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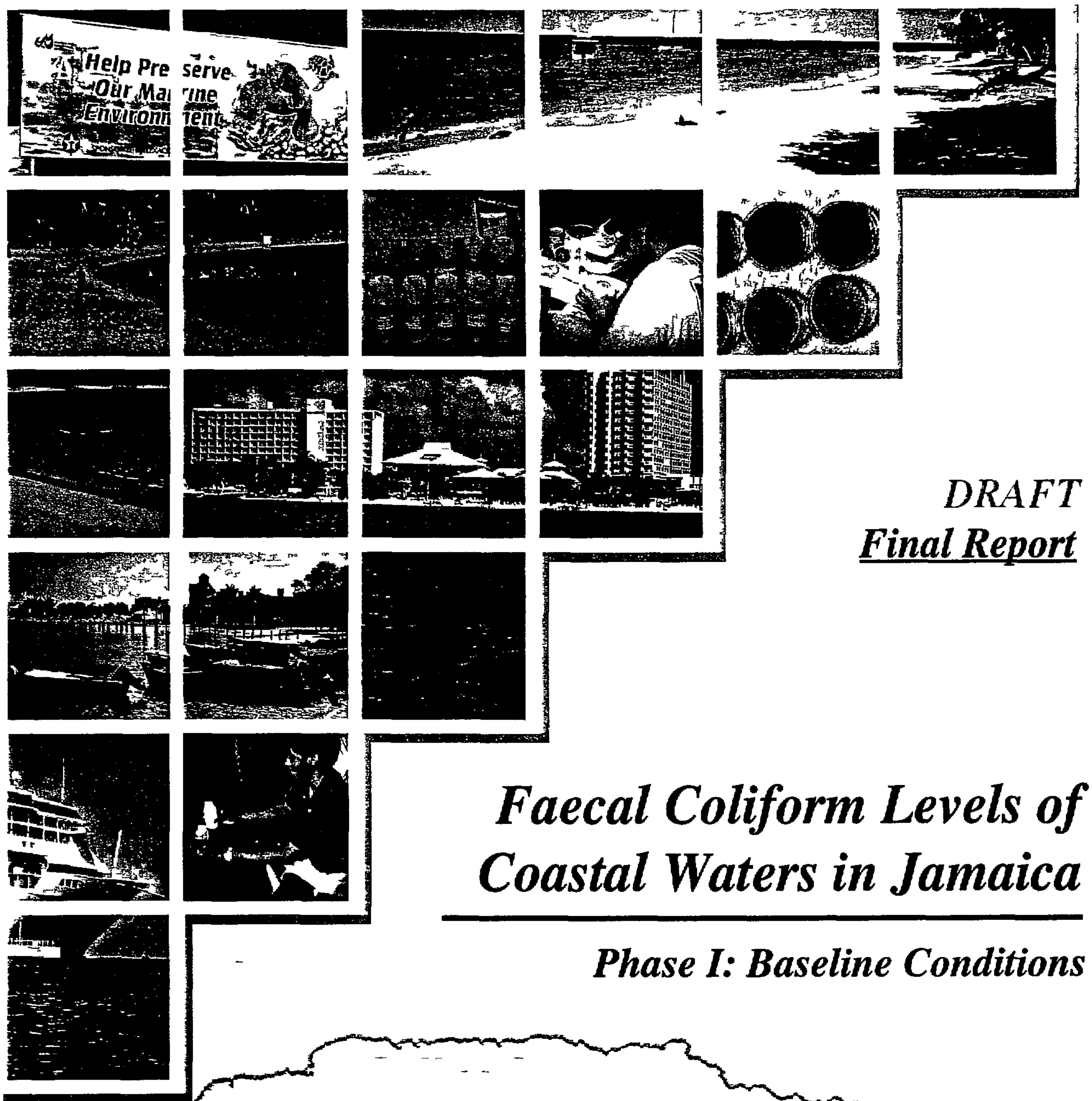
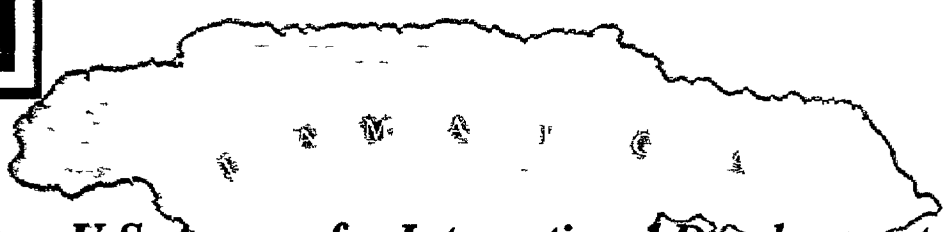


DRAFT

Final Report

Faecal Coliform Levels of Coastal Waters in Jamaica

Phase I: Baseline Conditions



U.S. Agency for International Development

Development of Environmental Management Organizations Project

USAID Contract No 532-0173-C-00-4188-00

Louis Berger International, Inc.

under contract to

Technical Support Services, Inc.

January 1998

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U.S. Agency for International Development

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Faecal Coliform Levels of Coastal Waters in Jamaica:

Phase I Baseline Conditions

Final Report

(DRAFT)

Prepared by

LOUIS BERGER INTERNATIONAL, INC

under contract to

Technical Support Services, Inc

JANUARY 1998

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EXECUTIVE SUMMARY

The objective of the study was to monitor the faecal coliform concentrations in areas surrounding four beaches to assess if the beaches are safe for swimming These beaches were located in the Ocho Rios Bay (Sailor Hole Beach and Turtle Beach), Montego Bay (Walter Fletcher Beach), and in Negril (Community Centre Beach)

A total of 1,258 samples were collected between August 26 and December 12 Samples were analyzed by a field laboratory set up for this project in Ocho Rios using techniques approved by the U S Environmental Protection Agency (USEPA) Outside quality control analyses were performed by the National Water Commission (NWC) laboratory in Montego Bay A laboratory intercalibration exercise was performed simultaneously with the laboratory of the Natural Resources Conservation Authority (NRCA) and a private laboratory (Kolbusch and Partners, Ltd)

Ocho Rios - Sailor Hole Beach

Findings

The beach receives faecal coliform mainly from two freshwater rivers Turtle River (source for over 95% of the coliform) and from Sailor Hole River

The faecal coliform concentrations along the Sailor Hole Beach exceeded the USEPA standard (from 1986) of 200 col/100 ml a total of 33% of the time The data represent largely dry weather conditions

Wet weather conditions were sampled on October 2 Samples were collected one hour before a medium-sized rainstorm (rain mount 20 mm), and again one hour and eight hours after the storm One hour after the storm faecal coliform concentrations had increased by one to two orders of magnitude, greatly exceeding the USEPA standard After eight hours, the concentrations had again declined to concentrations that still exceeded the USEPA standard slightly The data suggest that the beach exceeds the USEPA standard for swimming during most, if not all, medium-sized and larger rainstorms

Recommendations

The bathing public may need to be informed by local authorities that the beach exceeds the standard for swimming during and after rainstorms and, at times, during dry weather conditions

Improving the water quality along the beach requires improving the water quality of Turtle River A detailed survey of the entire watershed should be conducted in conjunction with efforts by the Water Resources Authority to identify all point sources to the extent possible Elimination of these point sources may at least improve the water quality along the beach to consistently safe bathing levels during dry weather

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Additional wet weather data collected during and after rainstorms are desirable to evaluate the effects of different types of rainstorms

Ocho Rios - Turtle Beach

Findings

The main point source for faecal coliform entering the beach appears to be a drainage pipe that empties into the central part of the eastern Ocho Rios Bay at the end of a small boat pier A second, but smaller, source is likely the stormwater drainage pipe entering the bay near Turtle Towers Other sources for coliform are cruise ships (if they illegally discharge wastewater), the Fern Gully Drainage Channel (potential source during large rainstorms), and small boats (although volumes would be small)

During dry weather conditions, the faecal coliform conditions in the eastern Ocho Rios Bay generally were low The USEPA standard was exceeded by up to 11% of the samples, depending on the station location in the bay The only exception was the station at the discharge point of the stormwater drainage pipe, where the faecal coliform concentrations exceeded the standard 32% of the time The highest concentration during dry weather conditions at that station was measured with 18,000 col/100 ml This high concentration suggests that the pipe may discharge wastewater from households and/or other establishments The volume of water discharged through the pipe may vary, which would explain the occasionally high faecal coliform concentrations during dry weather in other parts of the bay

During wet weather conditions, the faecal coliform concentrations in the eastern Ocho Rios Bay were high One hour after the rainstorm on October 2, the entire eastern Ocho Rios Bay greatly exceeded the USEPA standard The high concentrations were likely caused mainly by stormwater runoff that entered the bay through the pipe underneath the boat pier Residents stated that during storms, water can be seen bubbling up from the end-point of the pipe and the entire bay may turn brown Eight hours after the storm, the concentrations had mainly decreased to levels at around the standard

Other sources of contamination in the bay that were observed consisted of spills from bilge water and motor oil near boat piers Such sources can easily be avoided through responsible boat operation, supported by appropriate enforcement

Recommendations

Mitigation of wastewater entering the bay requires locating and disconnecting wastewater discharges from households and other establishments that currently enter the stormwater drainage pipes Connections should instead be established to the new sewage treatment plant This step would improve the water quality during dry weather conditions

However, stormwater discharges will most likely still carry high loads of coliform into the bay due to the multitude of small point and non-point sources Most likely, the only effective mitigation measure for maintaining safe bathing conditions along the beach during wet weather is the relocation of the stormwater drainage pipe One options consists of extending the pipe out to sea beyond the reef The second option consists of rerouting the discharge point to the east into the Fern Gully Drainage Channel This option may require pumping

Additional wet weather data collected during and after rainstorms are desirable to evaluate the effects of different types of rainstorms and to confirm that the drainage pipe is the main source of faecal coliform entering the bay These additional data would allow to determine the amount of rainfall required to increase the faecal coliform concentrations to levels above the USEPA standard The data would further provide important information for immediate management steps for the beach

Additional wet weather samples are also desirable from the second drainage pipe near the Turtle Towers It may be advisable to reroute the pipe along with the pipe underneath the boat pier

The bathing public may need to be informed by local authorities that the beach exceeds the USEPA standard for swimming during and after larger rainstorms

Boat maintenance regulations should be reviewed for small boats and be enforced At the same time, local authorities should create facilities on shore to facilitate easy compliance by the boat owners with such regulations

Montego Bay - Walter Fletcher Beach

Findings

During dry weather, the water along the Walter Fletcher Beach, as well as along the adjacent Dump-up Beach and One-man Beach, is typically safe for swimming, faecal coliform concentrations were very low However, during two of the 18 samples collected along the Walter Fletcher Beach during dry weather (October 27 & 28), faecal coliform counts were very high, greatly exceeding the USEPA standard of 200 col/100 ml The reason for the high values is not known, but they appear to have been caused by a one-time discharge Possibilities include a discharge through one of the two stormwater drainage pipes that enter Montego Bay through the rock groins on both sides of Walter Fletcher Beach, or a discharge from the sanitary facility at the beach

During wet weather the conditions at either one of the three beaches cannot be ascertained conclusively at this time due to the absence of sufficient rainfall during the study period Samples collected twice on days following a medium-sized rainstorm on the previous day had faecal coliform concentrations of up to 60 col/100 ml, indicating that at least 18 hours after a storm, the beaches were safe for swimming However, the faecal coliform concentrations were higher than during typical dry weather conditions, indicating that stormwater runoff does affect the beach The main sources of faecal coliform during wet weather are expected to be North Gully and the two stormwater drainage pipes in the rock groins Montego River and South Gully could be sources as well during very large rainstorms when the entire Montego Bay is affected (see report of the Montego Bay Environmental Monitoring Programme, Berger 1996)

Recommendations

Adequate wet weather data are needed to determine the water quality along the beaches during and shortly after rainstorms, and to determine the relative significance of the main sources for coliform for the beaches (i e , North Gully and the stormwater pipes that discharge along the rock groins)

The cause for the unusually high faecal coliform concentrations on October 27 and 28 should be explored further by investigating the existing sanitary facility on the property of the Walter Fletcher Beach and by assessing the drainage system that is connected to the two stormwater pipes The cause for the high concentrations must be eliminated before the beach can be considered safe for swimming during all dry weather conditions

Negril - Community Centre Beach

Findings

The faecal coliform concentrations along the Community Centre Beach are determined entirely by the brown water of the South Negril River upon entry into the ocean ("river plume") The river is tidal During the outgoing tide, the brown river plume moves either to the west, parallel to the cliffs, or to the north, parallel to the Community Centre Beach The direction of the plume appears to vary depending on the tides, current, and/or wind, the relative significance of these factors is not yet understood

When the river plume moves to the west, the water along the Community Centre Beach is turquoise blue ('blue-water conditions') Faecal coliform concentrations along the beach are very low to absent, the beach is safe for swimming

When the river plume moves to the north parallel to the beach, the water along the beach is brown The faecal coliform concentrations increase Depending on the volume of river water that is transported along the beach, the faecal coliform concentrations may or may not exceed the USEPA standard for swimming "Brown-water conditions" were observed on two days during the study period extending for approximately 1 kilometer along the beach from the mouth of the river During these two days the faecal coliform concentrations exceeded the USEPA standard at some stations along the stretch of the Community Centre Beach, concentrations in the brown water further away from the mouth of the river did not exceed the USEPA standard "Light brown conditions" were observed along the beach on some of the days during the study period, faecal coliform concentrations were higher than during "blue-water conditions" but never exceeded the USEPA standard

Most of the data that were collected represent dry weather conditions During rainstorms faecal coliform concentrations in the river are expected to be higher (although sufficient data do not yet exist) Higher faecal coliform concentrations in the river should result in higher concentrations along the beach, if the plume was to move to the north during the following outgoing tide However, this assumption needs to be investigated

The salinity along the beach was lower during "brown-water conditions" reflecting the influence of the river water The salinity of the downstream part of the South Negril River was approximately 25 parts per thousands (ppt), although it varied considerably for a variety of reasons The salinity of the ocean water was approximately 35 ppt During "brown-water conditions", the salinity along the beach varied between 29 and 33 ppt Initial data showed a high correlation between salinity and faecal coliform concentrations Therefore, salinity (along with color identification) may become a simple-to-use management tool for the Community Centre Beach Salinity measurements are immediate, requiring less than 10 seconds, faecal coliform analyses require a laboratory and are not available for over 24 hours Additional simultaneous salinity and faecal coliform data during "brown-water conditions" are needed to complete the development of this tool

Recommendations

The main sources of faecal coliform that discharge into the river should be identified These sources should be eliminated through connection to the new sewage collection system in the Town of Negril

Additional data during "brown-water conditions" along the beach are needed, as well as data during and after rainstorms Depending on these data, a management plan for the beach should be developed

Initial data indicate that salinity measurements along the beach could be a useful and simple-to-use management tool, as discussed above The additional faecal coliform and salinity data during 'brown-water conditions' should complete the development of salinity as a management tool

Procedures to assure proper performance of the new sewage treatment plant are important to avoid impacts to the beach Effluent quality monitoring should be conducted immediately starting with the operation of the plant

Summary

All four beaches have water quality problems under certain conditions These conditions are distinctly different at each one of these beaches The only common problem at these four beaches is that rainfall generally increases the faecal coliform concentrations The amount of increase depends of the proximity of the beach to stormwater runoff pathways (such as rivers, gullies, and drainage pipes)

The good news is that measures can be implemented to either reduce the sources of coliform to these beaches, and/or to manage these beaches to reduce the risk to human health during adverse conditions Again, source reduction measures and management options are very site-specific and thus unique for each beach Options for each beach are outlined in this report

With a management plan in place and with the implementation of specific source reduction measures, these beaches can remain a resource without unnecessary risks to human health

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Recommended Activities during Future Phases

Beach Management Plan Rather than closing these beaches at all times, each of the beaches should have a management plan to adopt measures for times of adverse conditions to avoid risks to human health Much of the data needed for such plans are available from this study However, additional data are needed for a complete understanding of the range of common water quality conditions along the beach before such a management plan is completed Such data consist mainly of faecal coliform concentrations during and after a number of rainstorms

Coliform Source Identification Ultimately, the source of contamination should be mitigated Therefore, the main sources of faecal coliform should be identified and eliminated in the medium-term, as feasible Given that all three communities are in the process of completing a new wastewater treatment plant, new options exist for the removal of some of the sources that currently enter the coast via river, gully, or pipe

Long-term Monitoring Plan Over the long term, the beaches should be monitored by the Natural Resources Conservation Authority (NRCA) The long-term monitoring plan needs to incorporate monitoring under dry weather as well as wet weather conditions Before recommendations can be made that consider the full range of common conditions that affect the beach, additional wet weather data are needed

NRCA Training Programme The laboratory equipment that was purchased for this project will be given to the NRCA Effective use of the equipment requires a training programme, since the staff of the NRCA is currently not familiar with the standard USEPA-approved Membrane Filtration Method Additional training is also recommended based on the results of the laboratory intercalibration activity We propose to combine the training programme for the NRCA with the collection of additional data toward the development of a management plan for these beaches

1.0 INTRODUCTION

1 1 Background

The tourism industry is an important source of income for Jamaica, specifically for communities along the North Coast In 1996, Jamaica had approximately 1 8 million visitors (including cruise ship travelers) who spent US$1 1 billion Approximately 67% of the tourist arrived from the United States Tourists are attracted to Jamaica in part because of its pristine beaches At the same time, the growing population and the increasing number of tourist facilities increase pressures on the natural resources One of these resources are beaches in the more urbanized areas, specifically beaches in the vicinity of rivers and gullies Due to the limited sanitary facilities on the island, rainstorms result in increased faecal coliform concentrations in coastal waters near discharge points

Recently, the Natural Resources Conservation Authority (NRCA, 1996) conducted a study on the coastal water quality of tourist areas in Jamaica The report concluded that along many of its beaches, the water is safe for bathing However, at some of the beaches in Jamaica, the water quality exceeded the USEPA standard of 200 col/100 ml for recreational water These beaches included the Sailor Hole Beach and Turtle Beach (Ocho Rios), the Walter Fletcher Beach (Montego Bay), and the Community Centre Beach (Negril) The NRCA study stated further that the faecal coliform concentrations were higher after flood and heavy rainfall events Similarly, elevated faecal coliform concentrations in coastal waters near Walter Fletcher Beach were measured during the Montego Bay Environmental Monitoring Programme in 50% of the samples (n=14) over 5 years (Berger, 1996)

Louis Berger International, Inc (Berger) has been contracted by the U S Agency for International Development (USAID) to study the four beaches discussed in the NRCA report in more detail The project has been a part of USAID's *Development of Environmental Management Organizations Project* (DEMO), that is managed by Technical Support Services, Inc

This report presents the findings and recommendations based on four monitoring events conducted over four months Recommendations for the protection of human health are provided to the extent possible with currently available data

1 2 Study Sites

The four beaches are located in three communities along the North Coast of Jamaica (Figure 1-1) All four beaches are close to areas with urban developments, although the population density varies considerably

Ocho Rios (Sailor Hole Beach and Turtle Beach) The Sailor Hole and Turtle Beach are located along the Ocho Rios Bay (Figure 1-2) The bay is an integral part of the Town of Ocho Rios The two beaches are used by local residents and visitors to the Town

Montego Bay (Walter Fletcher Beach) Walter Fletcher Beach is located on the eastern side of Montego Bay (the water body) The beach was artificially created through filling of shallow coastal

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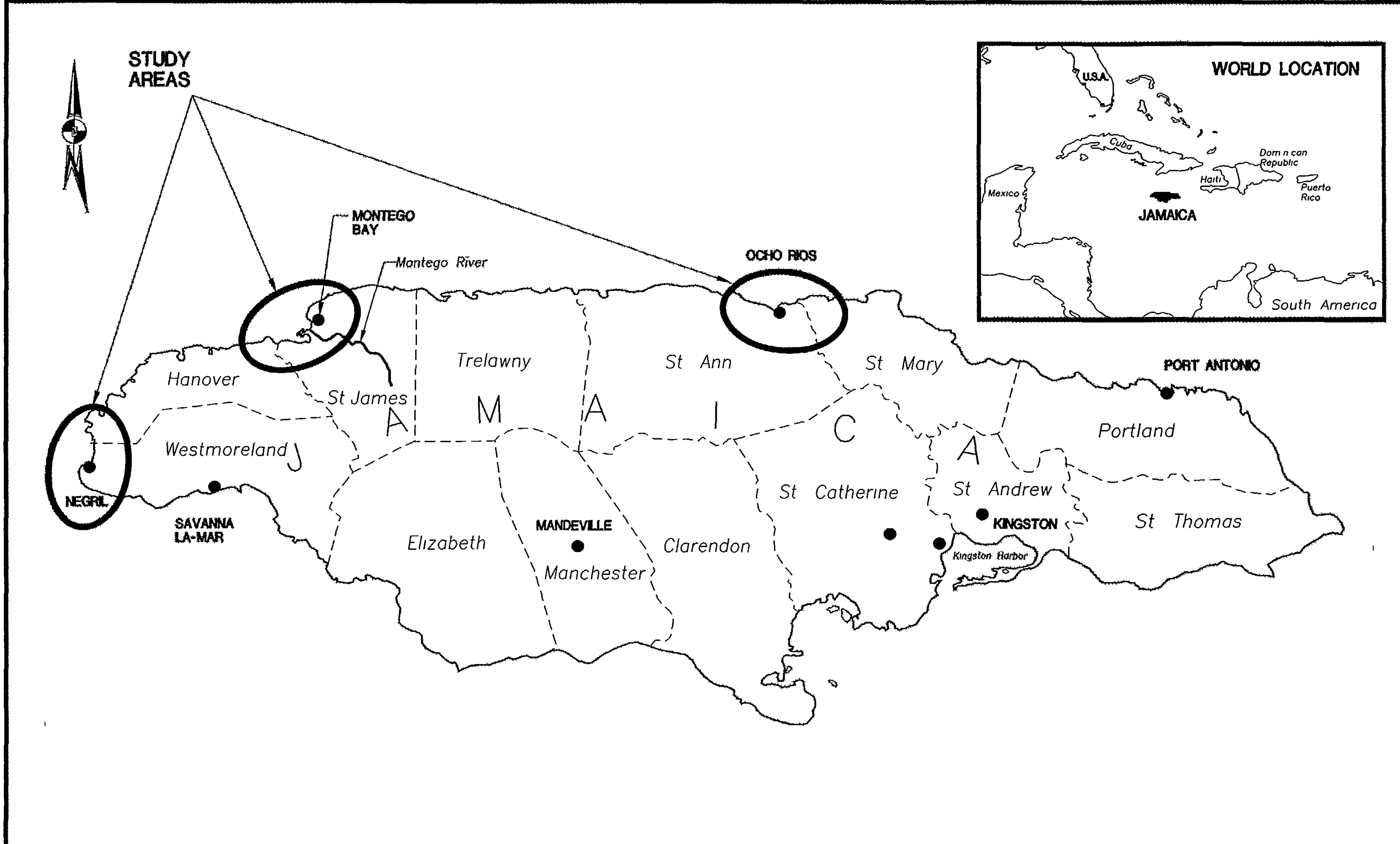

US AGENCY FOR INTERNATIONAL DEVELOPMENT LOUIS BERGER INTERNATIONAL, INC Technical Support Services, Inc	COASTAL WATER QUALITY MONITORING Scale 1 cm = 10 km December 1997	Figure 1-1 LOCATION OF STUDY AREA

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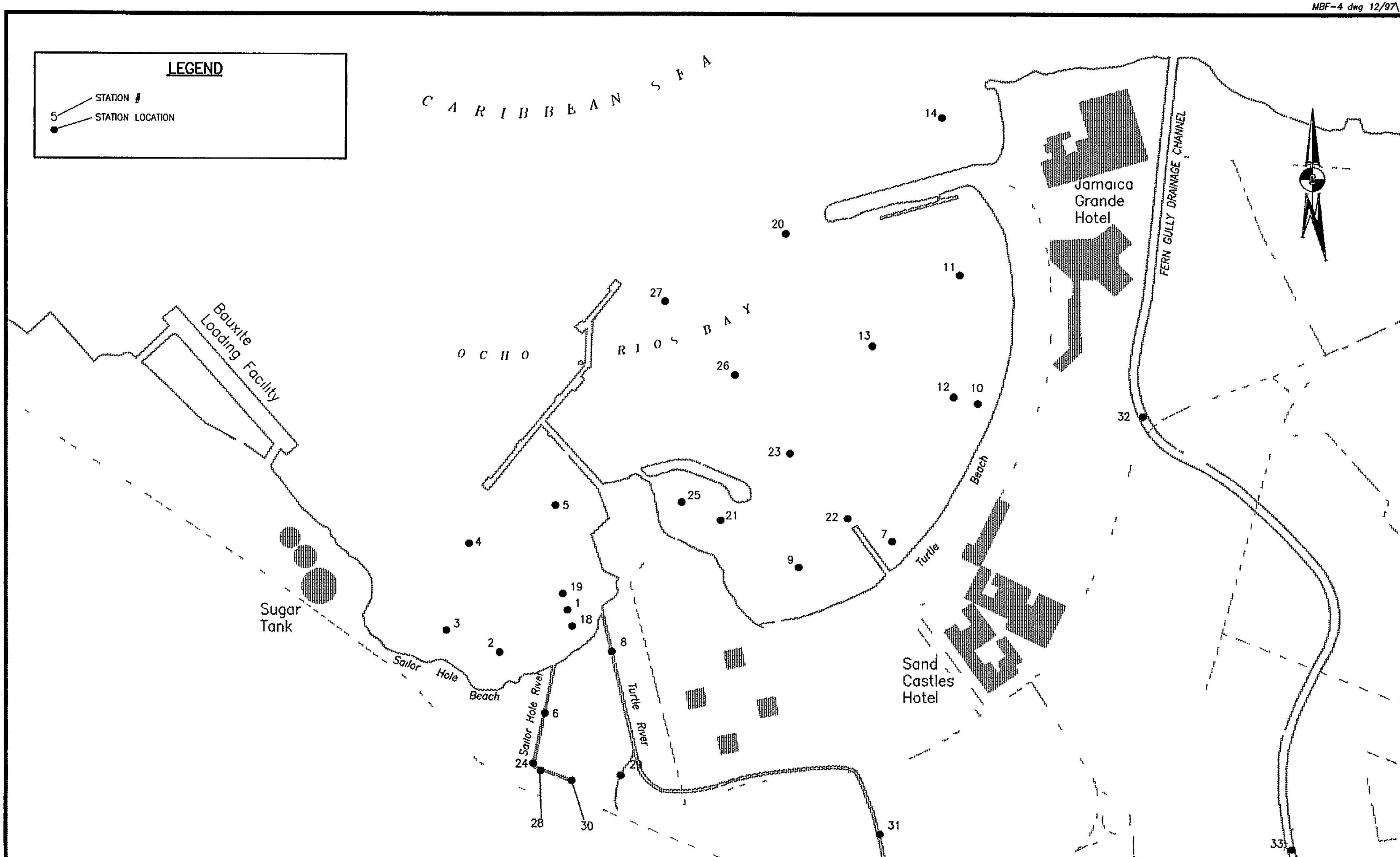

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Technical Support Services, Inc

COASTAL WATER QUALITY MONITORING

Approximate Scale
1cm = 120 meters

December 1997

Figure 1-2
OCHO RIOS
Station Locations

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lands in recent years The beach is in the middle of a string of three beaches with Dump-up Beach to the south and One-man Beach to the north (Figure 1-3) Each beach is protected by a rock groin structure

Negril (Community Centre Beach) The Community Centre Beach is located to the south of the well-known 7-mile long beach located along Long Bay in Negril (Figure 1-4) The beach is located adjacent to a Community Centre for the Town and is easily accessible to the public

1 3 Report Organization

The report is organized into eight sections and five attachments as follows

Section 2 - Water Quality Indicators for Human Health - Overview A brief overview of bacteriological indicators used for assessing water quality for human health This overview includes faecal coliform

Section 3 - Methodology Description of sampling methods and analytical procedures This section also describes the quality control measures that were important to this project

Section 4 - Ocho Rios - Sailor Hole Beach and Turtle Beach Each of the beaches at the three study sites is influenced by a unique set of parameters Therefore, each of the sites is discussed in a separate chapter, consisting of an overview of the site, a presentation and discussion of the data, recommendations toward a management plan, and suggested additional activities

Section 5 - Montego Bay - Walter Fletcher Beach

Section 6 - Negril - Community Centre Beach

Section 7 - Long-term Monitoring Plan A few comments about long-term monitoring of the four beaches

Section 8 - Summary Summary of main conclusions

Attachments A to C Tables with all analytical data for Ocho Rios, Montego Bay, and Negril, respectively Data are summarized by each one-week sampling event, there were a total of four events during the study These tables include key statistical values Some of the mean and maximum concentrations are presented further on overview maps

Attachment D Quality control data Quality control was conducted both internally through field duplicates (as well as by other measures discussed in Section 3 0), and through analyses of duplicate samples by the NWC laboratory in Bogue

Attachment E Data obtained as part of the laboratory intercalibration effort between four laboratories NRCA, NWC (Bogue), Kolbusch and Partners, and Berger's field laboratory The attachment presents the data along with a discussion and recommendations

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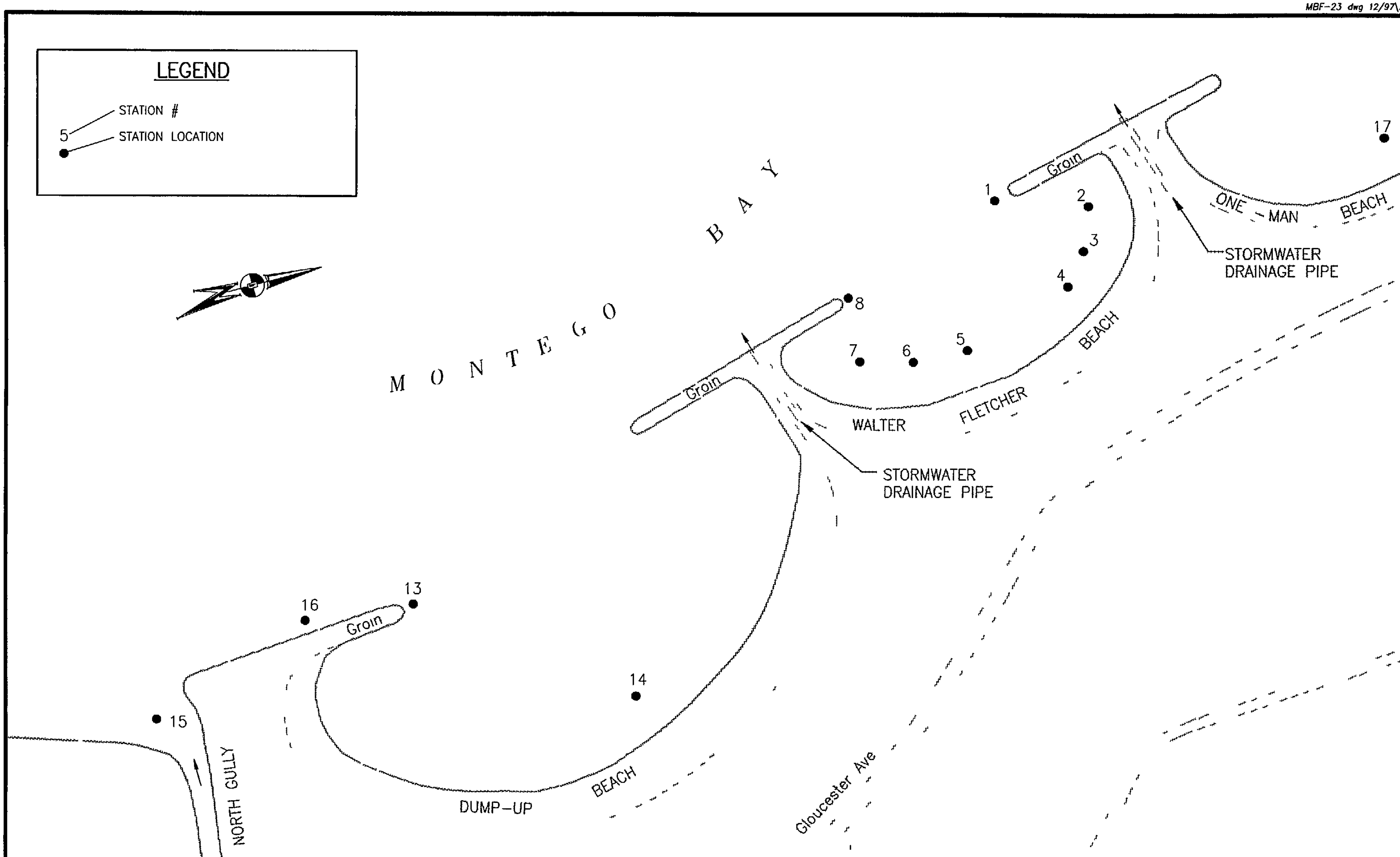

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT

LOUIS BERGER INTERNATIONAL, INC

Technical Support Services, Inc

COASTAL WATER QUALITY MONITORING

Scale 1cm = 40 meters

December 1997

Figure 1-3
MONTEGO BAY
Station Locations

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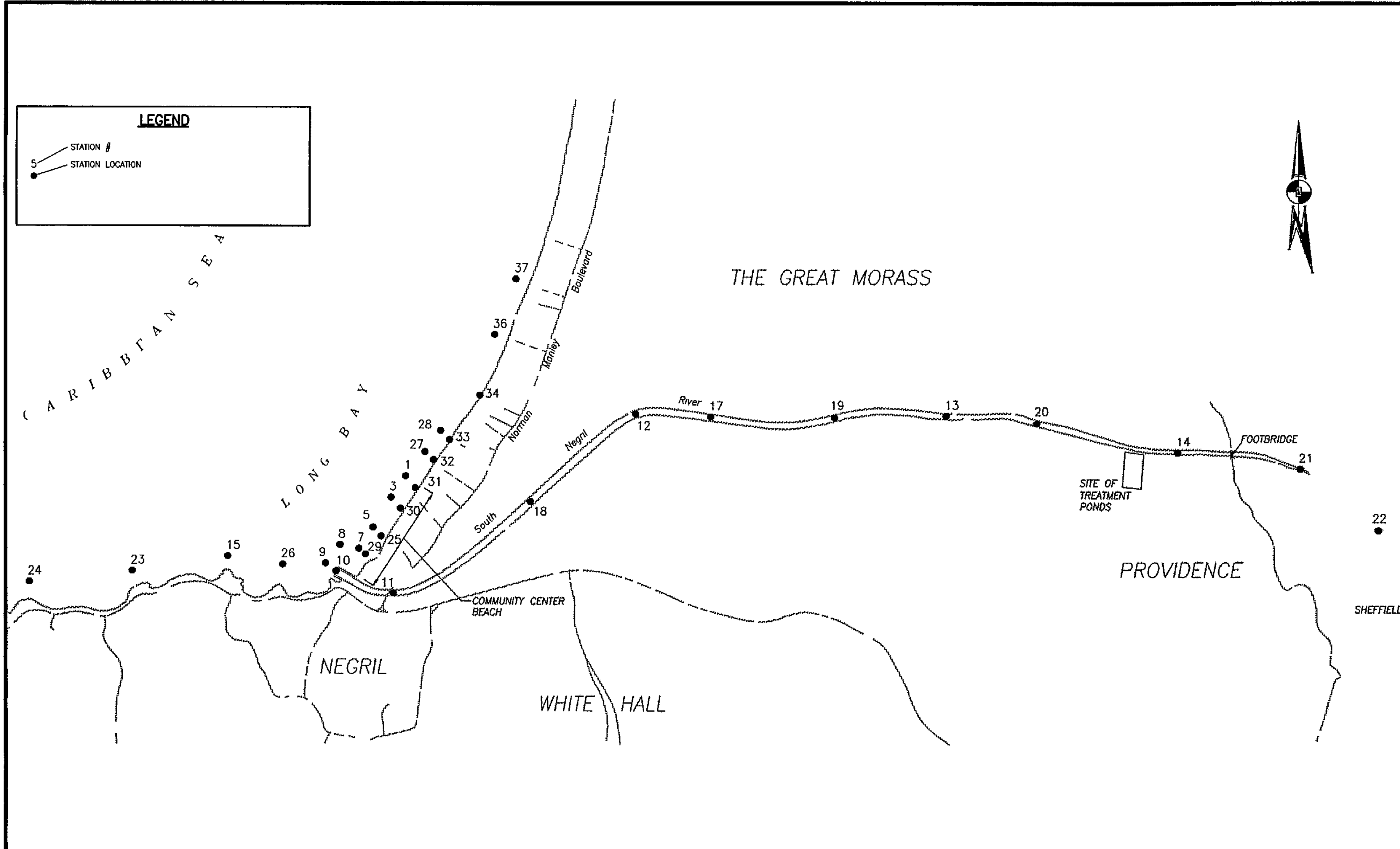

US AGENCY FOR INTERNATIONAL DEVELOPMENT LOUIS BERGER INTERNATIONAL, INC Technical Support Services, Inc	COASTAL WATER QUALITY MONITORING Scale 1cm = 200 meters December 1997	Figure 1-4 **NEGRIL** **Station Locations**

2.0 WATER QUALITY INDICATORS FOR HUMAN HEALTH - OVERVIEW

Water contaminated by sewage contains pathogens Pathogens are disease-causing organisms The goal of water quality monitoring for pathogens is to protect the public health by keeping exposures to below levels which cause illnesses A second goal is to use the data for the identification of pathogen sources and to guide appropriate management and regulatory actions

This section presents an overview of the use of microbial indicators to measure pathogens in water This overview includes faecal coliform which is widely used as an indicator of sewage-associated pathogens and which was used as an indicator in this study The overview does not include organisms that are less frequently used as indicators for other pathogens such as helminths and protozoa This section was included in part because the NRCA will be developing recreational water quality standards later this year, results from this study may aid in the evaluation of appropriate standards for Jamaica

2 1 Microbial Indicators of Water Quality

Protection of public health from diseases transmitted by exposures to sewage contaminated waters requires both the identification and treatment of contaminant sources and the ability to test waters for contamination Unfortunately, direct detection of water-transmitted pathogens is extremely difficult Perhaps the greatest problem with screening waters to protect human health using direct detection of pathogens is that each potential pathogen would have to be counted This would require the simultaneous measurement of different pathogenic species within widely divergent groups including bacteria, viruses, parasites and protozoans For pathogenic viruses alone, there are more than 120 distinct individual organisms in sewage The most common viruses of concern to recreational waters cause gastrointestinal illness and are known as enteric viruses Enteric viruses include enteroviruses, rotaviruses, astroviruses, caliciviruses, Hepatitis A, Norwalk virus, etc (Willams & Akin, 1986, West, 1991) An additional difficulty of direct enumeration of pathogenic bacteria and viruses is that they are able to produce illness even when their levels are low which requires that large volumes of water need to be analyzed The European directive on enterovirus in beach waters is based on 10 liters, while comparable Australian monitoring used 100 liter samples (Ashbolt, 1996) In addition, not all pathogens can be cultured and therefore are not easily detected from marine waters

For these and other reasons it has not been feasible to use direct pathogen counts for general water quality monitoring Instead, microbial indicators have been developed which indicate the potential presence of pathogens These microbial indicators have then been used to support empirically derived water quality standards aimed at protecting public health These indicators include (coliforms, faecal coliform, and enterococcus) Microbial indicators are not pathogens

Several traits contribute to the selection of a microbial indicator An ideal indicator for human pathogens in water should have the following traits (adapted from Metcalf, 1978,cf McNeill, 1991)

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- be present in wastewater and appear in polluted water whenever pathogens are present,
- not appear in unpolluted water,
- occur in much greater numbers than associated pathogens,
- occur in numbers relative to the degree of pollution,
- have a higher survival rate than pathogens,
- be applicable to various types of waters (marine water, freshwater)
- have detection methods which are sensitive and accurate and straightforward,
- have non-site specific characteristics,
- not be able to replicate within natural waters, and
- be safe to handle and process

At present, all indicators for pathogens caused by sewage contamination are microbial The microbial indicators coexist together with pathogens in the gastrointestinal tracts of man and warm-blooded animals However, unlike pathogens, the microbial indicators commonly used for water testing exist at very high levels in the gastrointestinal tract Therefore, they are potentially good tracers of sewage contamination and associated water-borne pathogenic organisms

Total coliform bacteria are used as one of the more common microbial indicators Total coliforms are made up of faecal and non-faecal coliform species Human waste contains large numbers of these bacteria in excess of 50 million coliforms per gram and more than 3 million per 100 ml The very high numbers of faecal coliforms in untreated sewage can be seen in a study of the Montego Bay wastewater treatment facility (prior to the ongoing upgrade) where average concentrations over five years were approximately 12 million col/100 ml Commonly analyzed coliform bacteria include also *Escherichia coli (E coli)* and faecal streptococcos (enterococcos)

The microbial indicators that are commonly used for water testing typically do not cause diseases This aspect is important as it avoids some of the health concerns during the sample analyses in water quality laboratories Coliform bacteria are almost entirely non-pathogenic to man, with only a few strains of faecal coliforms causing diarrhoea potentially fatal to new-born infants Coliform bacteria can also cause some problems through their ability to pass drug-resistance to pathogenic organisms Of the more than 2 billion coliforms excreted by the average adult per day, about 2% have drug resistant genes The drug resistant pathogenic bacterium, *Shigella dysenteriae* caused an outbreak of bacillary dysentery in Central America (1968-1971) from contaminated water, where more than 112,000 cases were reported for Guatemala alone (Mara, 1976)

At present, total coliforms are used as an indicator of sewage contamination in warm climates such as Jamaica However, tests for faecal coliform bacteria or a single species of faecal coliform (*E Coli)* or another group of enteric bacteria (enterococcus) are more appropriate Total coliform concentrations are affected by the growth of non-faecal coliform bacteria in the receiving waters with high comparatively high temperatures (Mara, 1976) In contrast, faecal coliform bacteria (and pathogens) show much less tendency for growth in the environment They therefore represent a better indicator for sewage contamination and for the protection of human health

Other indicators for pathogens in water that is used for contact recreation (e g , swimming) are still being investigated worldwide Studies in recent years suggest that, while the use of faecal coliform as indicators for health risks in water is an improvement over total coliforms, faecal coliform is less accurate in some applications than the use of the microbial indicator enterococcus (USEPA) Although faecal coliform is still widely used, enterococcus and *E coli* are becoming preferred indicators based on epidemiological studies (see below)

2 2 Water Quality Standards

At present, the Natural Resources Conservation Authority (NRCA) is developing water quality standards related to pathogenic contamination Standards were passed recently for sewage and trade effluent using faecal coliform bacteria as the pathogenic indicator Faecal coliform concentrations in sewage discharges are not to exceed 200 col/100 ml, while trade effluent must have concentrations of less than 100 col/100 ml

Ambient water quality standards are also being developed by the NRCA with draft values expected in approximately three months Recreational water quality standards will follow and are expected to be in place by the end of this year

At the present time, the USEPA and World Health Organization (WHO) standards are being used as guidelines for recreational water quality in many regions of the world, including in Jamaica The historic faecal coliform standard set by USEPA in 1986 for primary contact recreational waters (e g , swimming, bathing, etc) is a geometric mean of 200 col/100 ml based on a minimum of 5 samples collected over an interval of less than 30 days However, if more than 10% of the samples exceed 400 col/100 ml, the standard is also exceeded The reason for this 2-tiered standard is that in some environments with higher faecal coliform levels, a single exposure can reach the threshold of low but unacceptable health risks (Godfree et al , 1990) The historic USEPA standard from 1986 is currently in use by most of the coastal states of the United States It is important to note, however, that while the standard is still used by state regulators, the USEPA is currently recommending a shift to enterococcus or *E Coli* indicators (see below)

The European Economic Community has developed faecal coliform standards for bathing waters (both for freshwater and saltwater) with a guideline of 100 col/100 ml and a mandatory limit of 1 000 col/100 ml (recently revised down from 2,000 col/100 ml) However, less than 5% of the samples can exceed the mandatory limit

The difficulty in assigning a single indicator threshold for water quality is that the indicator organisms survive differently in different environments freshwater versus saltwater, sediment versus overlying water, temperate versus tropical climate, etc Furthermore, the health risk is related to the use to which the water will be put The clearest and most critical standards are for drinking water Potable water standards were the first to be developed as they had a clear and demonstrable relation to human health risks through pathogens associated with sewage contamination Given the severe health consequences (e g , typhoid, cholera, etc) of drinking sewage contaminated drinking water, the generally accepted standard is a total coliform concentration of 1 col/100 m The criterion was developed based on the general ratio of pathogenic bacteria to coliforms in wastewater of 1 1,000,000, and virus to coliform ratio of 1 100,000 Since

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pathogens generally decrease at similar or greater rates than coliform bacteria in the environment, the standard provides a significant level of statistical safety

Indicator standards for swimming, bathing and other water-based recreation have been much more difficult to determine than for potable water and are still being revised and improved Unlike diseases associated with drinking sewage-contaminated water, diseases stemming from contact exposures to contaminated waters such as through bathing or swimming tend to be minor and require no treatment or respond readily to treatment The most common contact illness is gastroenteritis which occurs in a variety of forms and is produced from a variety of viruses The symptoms are nausea, vomiting, stomachache, diarrhea, headache and fever Other minor illnesses associated with swimming are infections of the skin, ear, eye, nose and throat Contact with highly contaminated waters can result in the contraction of diseases associated with drinking water such as dysentery, hepatitis, cholera and typhoid fever (USEPA, 1997, West, 1991, Table 2-1) Fortunately, there is no evidence that the HIV virus can be transmitted by drinking water (Riggs, 1989) or improper sewage disposal (Slade et al , 1989)

Table 2-1

Potential illnesses associated with swimming in sewage contaminated waters

The common illnesses associated with swimming are gastroenteritis, fevers, nausea and infections of the skin, eye, ear, nose and throat

Pathogen	***Disease***
Bacteria	
E Coli	Gastroenteritis
Salmonella typhi	Typhoid fever
Salmonella spp	Enteric fevers, gastroenteritis
Shigella dysenteriae	Bacterial dysentery
Vibrio cholera	Cholera
Viruses	
Rotavirus	Gastroenteritis
Norwalk virus	Gastroenteritis
Adenovirus	Respiratory and gastrointestinal infections
Hepatitis	Infectious hepatitis

Source Cabelli (1982) and National Resources Defense Council (1997)

Epidemiological studies of waterborne viral gastroenteritis and hepatitis have consistently been shown to be associated with faecal indicator bacteria However, extension of the coliform indicators from potable water to recreational waters has frequently not yielded good results and the USEPA has rejected total coliforms standards for contact waters as an inaccurate indicator Moreover, current international standards were derived in temperate waters and probably can only be applied to a limited extent for tropical waters (McNeill, 1991)

The current use of faecal coliform levels to gauge the suitability of waters for recreation and other contact activities stems from the potable water studies and from freshwater contact epidemiological investigations relating illness to total and faecal coliform levels These investigations determine that 400 col/100 ml of faecal coliform was the threshold for risk, therefore, for added safety a level of 200 col/100 ml was put forward (FWPCA, 1968) Over the years, studies have frequently not yielded clear results to support the use of total or faecal coliforms for bathing beaches (cf NcNeill, 1991) However, faecal coliforms have been shown, for example, to be a useful indicator of recent sewage pollution and associated pathogens in a study in the tropical marine waters of Brazil (35°C) Also, based on recent US studies, the USEPA has determined that in marine waters guided by the faecal coliform standard of 200 col/100 ml, there is a previously unacknowledged risk of 15 gastrointestinal illnesses per 1000 swimmers (6 per 1000 in freshwater) (McNeill, 1991)

While coliforms are still accepted as good indicators for pathogens in drinking water and some freshwater contact restriction, standards for swimming (primary contact recreation) are starting to shift to other indicator organisms, most commonly enterococcus and *E Coli*, particularly for marine waters Enterococcus is among the best documented of these 'new' indicator organisms The growing acceptance of enterococcus as a sewage pathogen indicator stems from its strong epidemiological basis Starting in the mid-1970s, a series of studies (e g , Cabelli et al , 1982) were conducted at marine beaches in the United States These studies indicated a direct linear relationship between the frequency of gastrointestinal illnesses in swimmers and the level of enterococci in the waters Moreover, the level of enterococci associated with swimmer illness was low (approximately 10 Ent/100 ml) These initial studies also evaluated faecal coliform indicators and found little relationship to health risk as did subsequent studies of bathing beaches in England (Fleisher et al , 1993) These studies support the contention that total coliform and faecal coliform levels are limited indicators of gastroenteritis risk in some marine environments

Continuing investigation of the predictability of indicators for sewage associated pathogens is adding support for a shift to enterococcus (or at least periodic dual measurement of faecal coliform and enterococcus) Recently, a large epidemiological study was conducted in the warm marine waters of southern California This study of illness related to swimming in warm ocean waters contaminated by urban-runoff is potentially relevant to Jamaica The study involved over 15,000 pre- and 13,000 post- beach-use epidemiological interviews The data indicated that swimming near the discharge from a storm-drain resulted in a 50 percent greater incidence of minor illnesses than swimming more than 400 meters away (Haile, 1996) The water was tested for faecal coliform, enterococcus, *E Coli*, and enteric viruses The study showed also that microbial indicators are useful for determining exposure to pathogens

The apparent utility of enterococcus as an indicator and the finding of an only limited relationship between faecal coliform levels and illness from swimming exposure has resulted in the promotion by the USEPA of new water quality standards for marine waters For saltwater, 5 samples over a 30 day period shall not exceed a geometric mean of 35 Ent/100 ml, for freshwater, the mean is 33 Ent/100 ml However, no single sample should exceed 104 Ent/100 ml for saltwater (61 Ent/100 ml for freshwater) within a designated bathing beach, 158 Ent/100 ml for saltwater (89 Ent/100 ml for freshwater) for moderate to full contact recreation, 276 Ent/100 ml for saltwater (108 Ent/100/ml for freshwater) for light use bathing, or 500 Ent/100 ml for saltwater (151 Ent/100 ml for freshwater) for low contact recreation In addition, the results from enterococcus studies indicate the need for environmental considerations, such as mixed salinity estuaries like Negril River, differential indicator survival in storm drains, etc) not just water use in determining water quality standards It appears that at the same indicator level in recreational waters the illness rate for marine water was 3 times higher than in the freshwater system (McNeill, 1991)

The use of enterococcus as the indicator of choice for recreational water uses has been slow to become established partly because it requires different protocols than faecal coliform which have good utility in consumptive water uses For example, the enterococcus measurement requires an incubation time of 48 hours rather than 24 hours for faecal coliform The added time makes rapid response to changing environmental conditions difficult

2 3 Indicators used in the Study

Faecal coliform was used as the main indicator in our study Faecal coliform is still a good indicator for specific situations For example, faecal coliform is a good tracer for sewage Since all four studied beaches receive sewage water to some extent, faecal coliform was important for identifying the sources for contamination and for tracing the transport path of coliform-laden freshwater rivers upon entry into the ocean In addition, faecal coliform is still commonly used worldwide including in the United States The large amount of data from waters of other coastal areas allow for intercomparisons, enterococcus is not yet widely used In our study, faecal coliform results were compared to USEPA standard from 1986 This standard consists of a faecal coliform concentration (geometric mean) of 200 col/100 ml with no more than 10% of the samples exceeding 400 col/100 ml

However, simultaneous analyses were also conducted during our study for enterococcus The tests were runs on approximately one quarter of the identical samples that were analyzed by our field laboratory for faecal coliform The enterococcus analyses were conducted outside of the Terms of Reference for this study, but were conducted because the setup of the project provided an excellent and rare opportunity for intercomparison between the two indicators on a significant number of samples At this stage, the data still need to be synthesized and compared to the faecal coliform results The comparison should prove to be useful as an additional assessment of health risks at the four investigated beaches It should also be useful for the NRCA for the development of recreational water quality standards for Jamaica

3.0 METHODOLOGY

3.1 Sampling

3 1 1 Sampling Events

Each beach was sampled during four periods in the fall of 1997

- *Sampling Event 1 (Reconnaissance, August 26 to 29)* This sampling event was conducted for reconnaissance purposes Each beach was sampled once (Montego Bay, Negril) or twice (Ocho Rios) to obtain baseline data for the understanding of the range of concentrations and potential number of stations required to properly characterize each site This information was then used to develop a more detailed sampling strategy and to define the analytical and laboratory requirements for follow-up sampling events

- *Sampling Event 2 (September 28 to October 3)* One week sampling event with daily sampling

- *Sampling Event 3 (October 26 to November 3)* One week sampling event with daily sampling

- *Sampling Event 4 (December 7 to 12)* One week sampling event with daily sampling

3 1 2 Sampling Stations

At each beach area, samples were collected at several different locations (referred to as "stations") These stations were located along the beaches as well as in the areas surrounding the beaches to try to relate the concentrations at the beaches to potential faecal coliform sources In addition to the coastal stations, water samples were collected from potential point sources for faecal coliform in order to better understand what is controlling coliform levels at each beach These point sources included the Turtle River and Sailor Hole River (Ocho Rios), the North Gully (Montego Bay), and the South Negril River (Negril) The number of sampling stations was modified to varying degrees after each sampling event, specifically after the first event During the more intensive Events 2 to 4, most of the stations were sampled regularly, additional stations were added intermittently for purposes of further reconnaissance Station locations for each site are listed in Figures 1-2 (Ocho Rios), 1-3 (Montego Bay) and 1-4 (Negril)

3 1 3 Sampling Frequency

The sampling frequency varied for the different beaches During the intensive Events 2 to 4, every beach was sampled at least four times In Ocho Rios, samples were collected most frequently due to the comparatively higher variability in coliform supply and the proximity of the site to our field laboratory Twice-daily sampling was typically conducted at the Ocho Rios and Montego Bay beaches This high frequency of sampling allowed for an evaluation of the short-term variation in faecal coliform levels resulting from differential inputs and differential die-off rates of coliform bacteria day versus night In addition, the high frequency of sampling provided the needed resolution of effects of short-term rain events The frequency of sampling and analysis in our laboratory (Figures 3-1 to 3-8) is presented in Table 3-1 The total number of samples that were analyzed in this study is listed in Table 3-2

3 1 4 Sampling Procedure

Samples were collected from a water depth of 20 cm in pre-sterilized bottles This depth was deep enough to avoid any effects of floating matter on the water, yet shallow enough to be representative of the depth for potential ingestion of water by swimmers Samples were collected by lowering the open sampling bottle upside down into the water column and then rotating the bottle in the direction of flow at the depth of 20 cm to fill it For duplicate samples, two bottles were held in the same hand to allow them to fill simultaneously (Figure 3-1) A head space was left in the bottle to allow mixing by shaking prior to analysis Sampling at each beach lasted between 30 and 60 minutes, sampling times reported in the data tables (Attachments A to C) reflect the time in the middle of this period

After sampling, the samples were placed into a dark cooler without ice if the analysis was to begin within 1 hour after collection, and with ice to maintain a temperature of 4 to 10°C for longer holding times Samples were then transported to a laboratory within 6 hours which is the recommended time between sampling and analysis (i e , "holding time") as specified by the U S Environmental Protection Agency (USEPA) Each batch of samples was delivered to the laboratory with a Chain of Custody form (Figure 3-2)

3 2 Laboratory Analyses

The main constraints for the analytical analyses were as follows

- High quality analyses using standard approaches with USEPA approved methodologies
- High level of quality control, both internally and through an outside laboratory
- Capability to run more than 80 samples per day if necessary, in order to be able to capture the variability of faecal coliform concentrations both in terms of space an time
- Capability for sample collection and analysis 24 hours a day if needed in order to be able to test for conditions after rain
- Proximity to the project location

3 2 1 Field Laboratory

Given these limiting requirements, we agreed with USAID to set up a field laboratory in Ocho Rios for the project The laboratory is fully capable of analyzing faecal coliform by the Membrane Filtration Method (Method No 9222D, Standard Methods, 19th ed) The method is approved by the USEPA and is the most common approach for monitoring pathogen contamination on marine beaches in the United States The capability of the field laboratory was equal to a state-of-the-art permanent laboratory Laboratory procedures complied with USEPA procedures and protocols The laboratory was assembled and operated by experienced microbiologists in our team An overview of some of the components of the laboratory are presented in Figures 3-3 to 3-8 The components of the laboratory were either purchased or rented for the study

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Figure 3-1 Water sampling in coastal waters for faecal coliform analyses Samples were collected from a water depth of 20 cm Here, duplicate samples are collected by Mrs Paulette Brown from the Natural Resources Conservation Authority (NRCA), as part of a laboratory intercalibration effort conducted also during this study

Figure 3-2 Samples collected from a single day of sampling (here Ocho Rios, December 11) At each beach and on each day, samples were collected at several stations within the area as part of an effort to understand the coliform sources and the variability in coliform distribution

Figure 3-3 Samples were analyzed for faecal coliform by a field laboratory set up in Ocho Rios for the study The laboratory used the U S EPA approved Membrane Filtration Technique, performed by experienced microbiologists on our team Quality control procedures were the same as for a permanent laboratory Shown here is Dr Brian Howes operating the sample filtration system

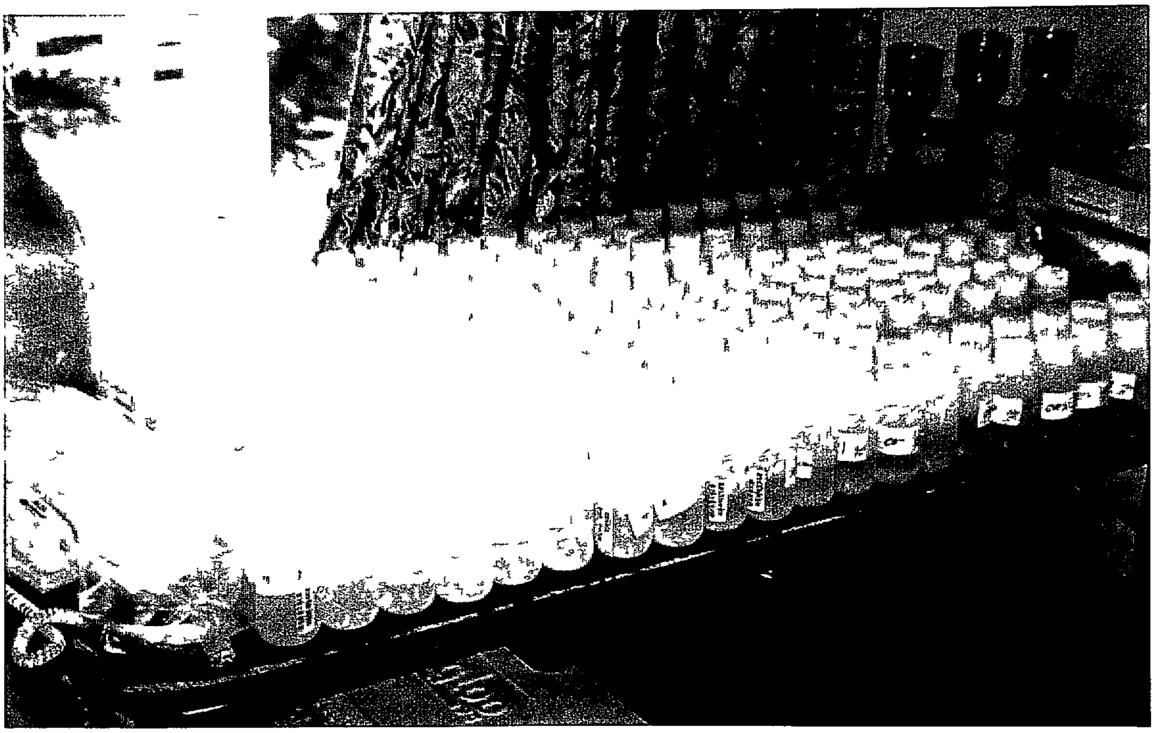

Figure 3-4 The field laboratory had the capability to analyze approximately 80 samples per day Shown here are approximately half of the samples that were analyzed during Sampling Event 4 by our laboratory

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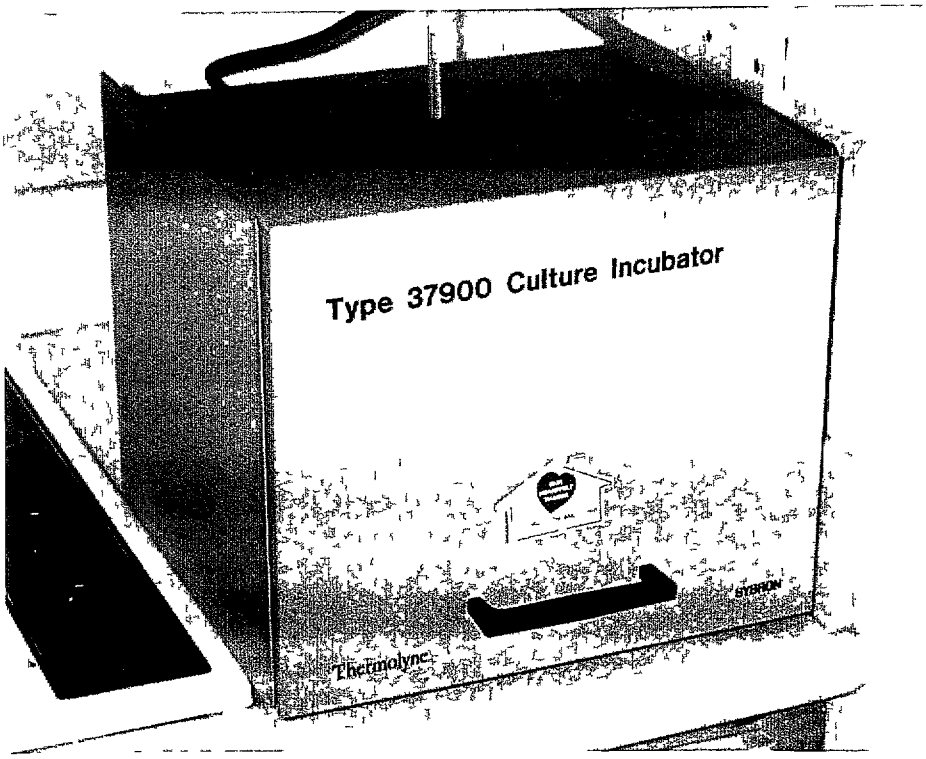

Figure 3-5 One of the four incubators used for different aspects of the sample analyses The shown incubator was used for the identification of the types of coliform bacteria on the sample plates

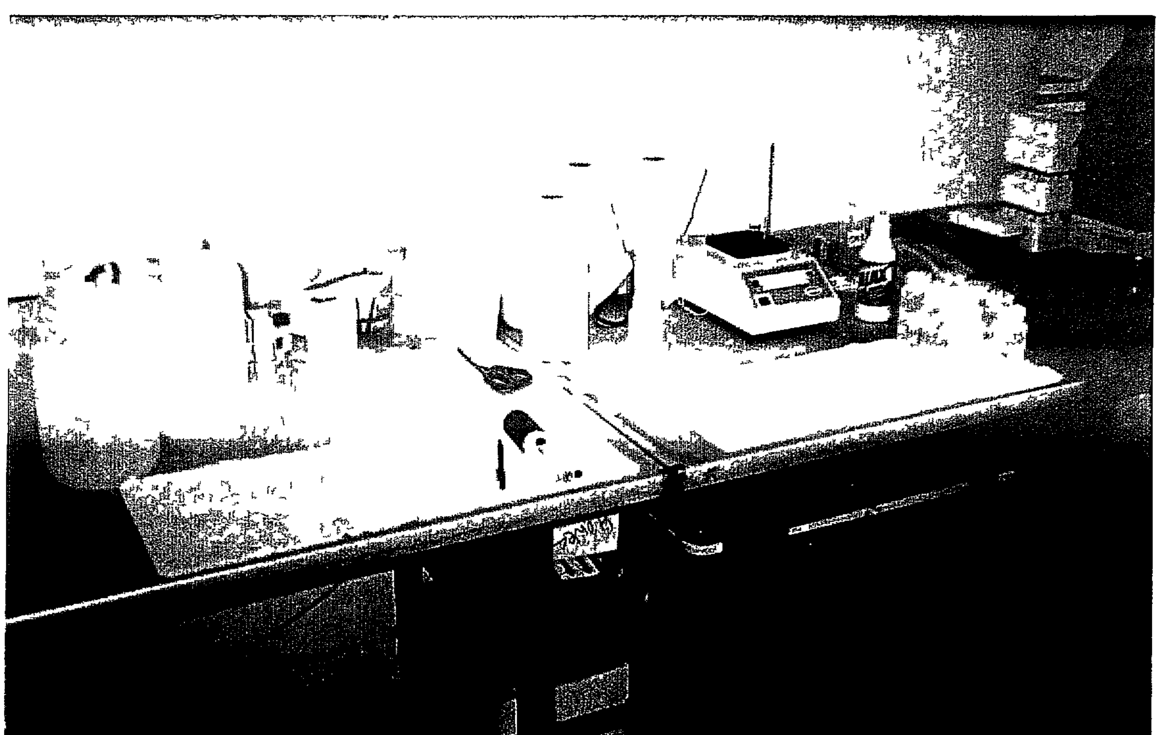

Figure 3-6 The incubator on this photograph was used for analyses to confirm that bacteria on the sample plates were indeed coliform bacteria, as another one the our quality control steps

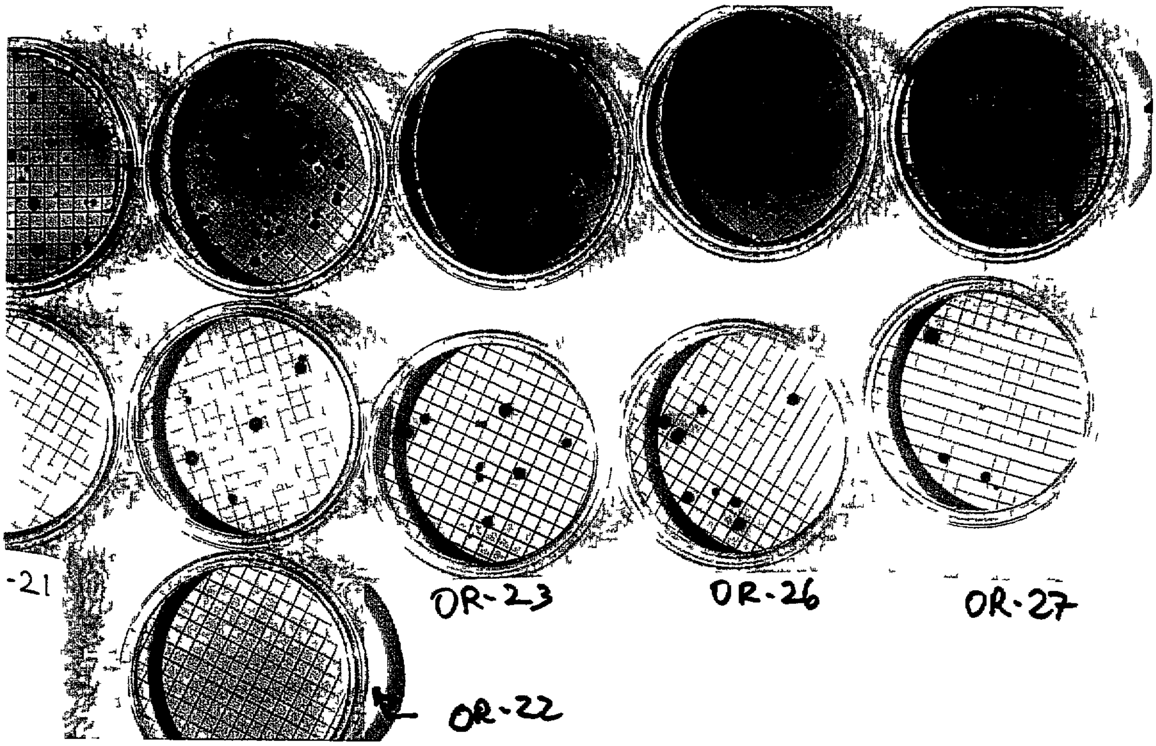

Figure 3-7 Plates with faecal coliform bacteria after 24 hours of incubation For each sample two or more plates were prepared with different levels of dilution The top row represents undiluted samples, the second row represents a 10-fold dilution of the sample, the third row (Station OR-22 only) represents a 100-fold dilution The concentration of coliform colonies on each filter decreases proportionately

Figure 3-8 The faecal coliform colonies on each plate were counted under the microscope by Mr Brian Connolly from our team

Table 3-1

Faecal Coliform Levels in Coastal Water in Jamaica

Sample Collection Periods per Site

	Sunday am	Sunday pm	Monday am	Monday pm	Tuesday am	Tuesday pm	Wednesday am	Wednesday pm	Thursday am	Thursday pm	Friday am	Friday pm	Saturday am	Saturday pm	Sunday am	Sunday pm
Sampling Event 1 (Reconnaissance) *Aug 26 to 29*																
Ocho Rios					●						●					
Montego Bay										●						
Negril									●							
Sampling Event 2 *Sept 28 to Oct 3*																
Ocho Rios		●	●	●	●	●	●	●●	●	●●	●					
Montego Bay			●	●	●	●			●	●	●					
Negril				●		●				●		●				
Sampling Event 3 *Oct 26 to Nov 1*																
Ocho Rios		●	●	●	●	●	●	●	●	●	●	●				
Montego Bay		●	●		●			●		●		●				
Negril				●		●				●					●	
Sampling Event 4 *Dec 7 to 12*																
Ocho Rios		●●	●	●	●	●		●	●		●					
Montego Bay		●		●		●	●			●						
Negril				●		●	●			●						

Key
- ● Marks that samples were collected during this period
- • A small dot indicates that only a few key stations were sampled
- ●● Two dots mark two sampling periods in the morning or afternoon respectively

Table 3 2

Faecal Coliform Levels in Coastal Water in Jamaica

Number of Sample Analyses

Sampling Event No	All Sites: Total No of Samples Analyzed	Ocho Rios: No of Samples Analyzed per Event	Ocho Rios: Berger Lab	Ocho Rios: NWC Bogue	Ocho Rios: NRCA	Ocho Rios: Kolbusch & Partners Ltd	Montego Bay: No of Samples Analyzed per Event	Montego Bay: Berger Lab	Montego Bay: NWC - Bogue	Montego Bay: NRCA	Montego Bay: Kolbusch & Partners Ltd	Negril: No of Samples Analyzed per Event	Negril: Berger Lab	Negril: NWC Bogue	Negril: NRCA	Negril: Kolbusch & Partners Ltd
Event 1	**73**	*52*		20		32	*9*		9			*12*		12		
Event 2	**398**	*274*	216	38	10	10	*64*	45	19			*60*	36	24		
Event 3	**425**	*257*	185	52	10	10	*68*	50	18			*100*	69	31		
Event 4	**362**	*168*	152	16			*68*	53	8	7		*126*	94	25	7	
Sum	**1,258**	***751***	**553**	**126**	**20**	**52**	***209***	**148**	**54**	**7**	**0**	***298***	**199**	**92**	**7**	**0**

The primary laboratory components include the filtration and sterilization station, highly stable incubators, counting station and confirmation station The filtration station consisted of a 6 port vacuum filtration manifold with glass 47 mm towers The UV sterilizer was keyed to the manifold allowing complete sterilization of all towers in 2 minutes Required incubators included a large capacity water bath for filter/plate incubations and a smaller incubator (2 temperature block incubator) for the confirmations Sample counting requires a stereo microscope with fluorescent ring and hand counter The confirmation station consisted of the 2 channel incubator and the sterile transfer supplies for the gas generation method

Upon return of samples to the laboratory, analysis began immediately as samples were logged in via chain of custody Samples were vigorously shaken at least 30 times before sub-samples were withdrawn for filtration or dilution The faecal coliform method used type HC filters (Millipore) which is specifically designed to improve recovery of stressed faecal coliform organisms (hence better accuracy) compared to the frequently used type HA filters (Sladek et al , 1975) All glassware was UV sterilized immediately before each use and forceps were flame-sterilized After filtration the filters were immediately transferred to the mFC agar plates (with Rosalic Acid), placed into sterile bags and put into the waterbath at 44 5°C within 15 minutes All incubations were for 24 ± 2 hours Filters were all counted immediately upon removal from the incubator using a stereo microscope with a fluorescent illuminator The dilution which yielded faecal coliform counts of between 20-80 on a filter was the one chosen as representing the best estimate for a sample Good agreement was achieved between dilutions for those samples with countable filters at multiple dilution levels (Attachment D) Plates with moderate to high numbers of non-faecal bacteria were not used In the few samples where plates at the greatest dilution level contained more than 100 faecal coliform colonies a special evaluation was conducted as to the validity of the data and whether the faecal coliform concentrations should be reported as greater than #col/100 ml Samples with high sediment loads were not encountered and all filters showed good distribution of colonies (i e , no clumping) Faecal coliform confirmation tests using the gas production approach which was applied throughout the study Visually identified colonies were incubated sequentially in lauryl tryptose broth and EC media and gas production were evaluated

In addition to the samples analyzed by our team, duplicate samples were regularly analyzed by the National Water Commission (NWC) laboratory in Bogue Selected samples were also analyzed by the Kolbusch and Partners laboratory in Kingston and by the laboratory of the Natural Resources Conservation Authority (NRCA) as part of a preliminary laboratory intercalibration exercise

A total of 1,258 samples were analyzed for faecal coliform during this project (Table 3-2) Of these, 900 samples were analyzed in a field laboratory that was set up in Ocho Rios by our team, 272 samples were analyzed by the NWC laboratory in Bogue, 34 samples were analyzed by NRCA, and 52 samples were analyzed by Kolbusch & Partners, Ltd Berger, NWC, and Kolbusch used the Membrane Filtration Method for sample analysis The NRCA lab and the NWC lab (for 5 additional samples only) used the Multiple Tube Fermentation Method for sample analysis

3 2 2 *Quality Control*

In the laboratory, laboratory duplicates and blanks were run on a routine basis following standard USEPA approved practices In addition, of the 900 samples analyzed by our field laboratory, 55 samples (6%) were field duplicates The laboratory personnel did not know the origin of the sampling station prior to analysis The concentrations in the duplicate samples closely matched the concentrations in the original samples (Attachment D) A total of 272 samples were analyzed by the NWC laboratory Of these samples, 15 samples were field duplicates

The results of these blind duplicate QA samples indicate a high degree of precision Of the 54 pairs of samples analyzed by Berger (one sample from Event 4 was not included for QA reasons), the average difference was about 10% (Attachment D) The precision of the analyses is further assessed from the linear regression of the duplicates from all of the sampling events The data were clearly directly related (slope=1 02) and showed little difference between paired samples (r^2=0 98) Similarly, the duplicates analyzed by the NWC laboratory in Bogue showed only slightly more variable results However, given the lower number of duplicates, the linear regression coefficient showed excellent replication (r^2=0 87 with a slope of 1 06) The two other laboratories in Jamaica had insufficient field duplicates to evaluate precision All of these analyses support the conclusion that the data were highly reproducible and that the method showed little variability in the analysis of natural samples by the same laboratory For the detailed QA/QC evaluation of the project data set see Attachment D

3 3 Laboratory Intercalibration

In collaboration with the NRCA, a laboratory intercalibration exercise was integrated into the project for Sampling Events 2 to 4 Integration into our programme was simple given our specific setup Members from NRCA participated in the sample collection (Figure 3-1) Participating laboratories were the NWC, NRCA, Kolbusch, and Berger's field laboratory Duplicate samples at selected stations for the different laboratories were collected at the same time by holding the appropriate number of bottles in one or several hands The bottles were all adjacent to each other and were dipped into the water at the same time

Samples were placed into separate coolers and were cooled with ice during their transport to the respective laboratories Samples were analyzed within holding time requirements A total of 34 samples were analyzed by the different laboratories as part of the laboratory intercalibration exercise For results of the effort, see Attachment E

3 4 Rainfall

Rain gauges were deployed in Ocho Rios and in Montego Bay Rain information for Negril was kindly made available by the Meteorological Office, the gage is located at the South Negril Lighthouse In addition, the Meteorological Office also provided long-term rain information for Montego Bay (Station at the Sangster International Airport) and the mountains south of Ocho Rios (Cole Gate - 6 km south of Ocho Rios)

3 5 Freshwater Flow Rates

Flow measurements were made for the rivers at the three sites In Ocho Rios, the flow was estimated for Turtle River and Sailor Hole River, as well as for the Fern Gully Drainage Channel For Montego Bay, the flow in North Gully was estimated No flow measurements were gathered from Negril, since the river is tidal the net freshwater inflow into the open ocean is more complex and requires a more detailed survey

3 6 Sediments

Sediment cores were collected in the western Ocho Rios Bay and from the area surrounding the end of the pipe in the eastern Ocho Rios Bay A total of 10 undisturbed cores were collected by a local diver The upper 1 cm of the cores was carefully sectioned off and analyzed for *clostridia* spores The data are still being reviewed and will be presented in a future report

3 7 Enterococcus

A subset of the samples from each beach were analyzed for both enterococcus and faecal coliforms This was done to provide insight into the development of water quality standards for these systems The data from the approximately 200 samples is still being reviewed and will be presented in a future report However, preliminary inspection of the results suggests that a relationship between faecal coliform and enterococcus levels exists at some of the more contaminated marine locations which suggests that faecal coliforms are likely good indicators at these sites

4.0 OCHO RIOS - Sailor Hole Beach and Turtle Beach

4 1 Overview

The two beaches are located in the Ocho Rios Bay This bay consists of an eastern and western part (Figures 4-1 and 4-2) The two parts are divided by port facilities for cruise ships Typically, there are one or two cruise ships in Ocho Rios during several days of the week Other port facilities surrounding the bay are a sugar holding tank and a bauxite loading facility to the west

Sailor Hole Beach is located along the western Ocho Rios Bay The beach consists of a public swimming beach to the east (Figure 4-3) and a beach section to the west in front of a small fishing community (Figure 4-4) Two rivers discharge into the western Ocho Rios Bay the Turtle River and the smaller Sailor Hole River (Figures 4-5 and 4-6) These rivers are in part fed by groundwater and therefore flow continuously throughout the year

Turtle Beach is surrounded by the Town of Ocho Rios and several residential and hotel developments The largest hotel is the Jamaica Grande Hotel (Figure 4-7) The beach area is fenced Access is available free of charge to visitors and residents of abutting developments Access is also available for a fee (J$30) for any other resident or visitor at a gate near the center of the beach The beach is actively used for recreational purposes (Figure 4-8) Boats are moored on either side of the eastern bay, as well as along a pier in the central part of the bay

The main sources for faecal coliform to the bay appears to be a pipe underneath the small boat pier Other potential sources consist of a second stormwater drainage pipe in the vicinity of the Turtle Towers, cruise ships (if they illegally discharge wastewater) (Figure 4-9), and potentially the Fern Gully Drainage Channel during large storms (Figure 4-10)

4 2 Data

4 2 1 Rainfall

Rain information for the study period is summarized in Tables 4-1a to 4-1b Samples for faecal coliform analyses were collected mainly during dry weather conditions During the sampling events, rain fell in the Town of Ocho Rios only on October 2 (Table 4-1b) On December 7, rain fell in the mountains south of Ocho Rios but not in the town itself, the rain affected the western Ocho Rios Bay through the Turtle River watershed, but not the eastern Ocho Rios Bay

4 2 2 Flow Rates

During dry weather conditions, the flow rates of the Turtle River was comparatively constant with an average of 0 57 m^3/sec (20 cubic feet per second [cfs]) The flow rate of the Sailor Hole River was also constant with approximately 0 20 m^3/sec (7 cfs)

35

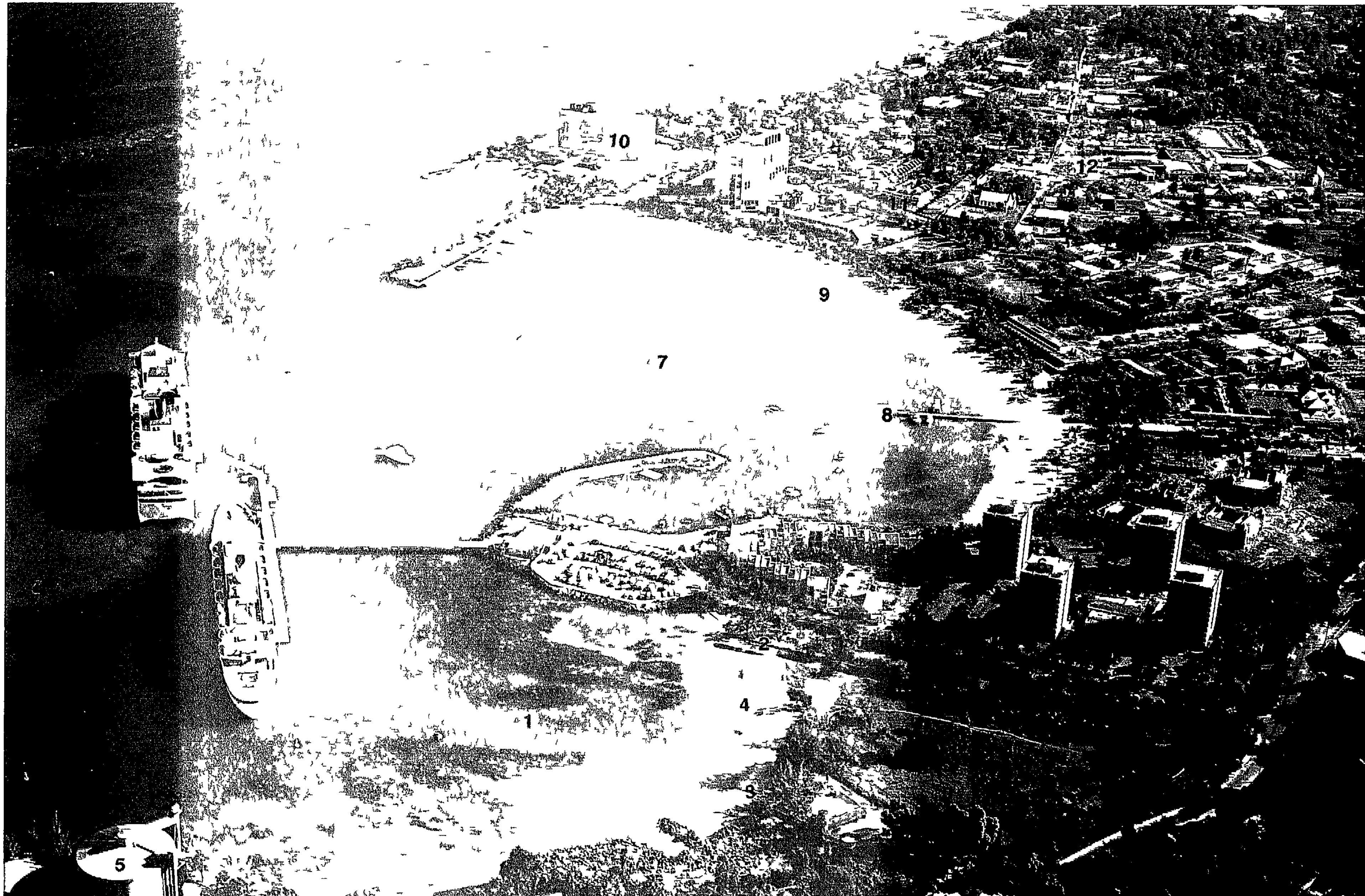

Figure 4-1 Ocho Rios Bay looking to the northeast. Key (1) Western Ocho Rios Bay (2) Turtle River (3) Sailor Hole River (4) Sailor Hole Beach, (5) Sugar Tank (6) Turtle Towers (7) Eastern Ocho Rios Bay (8) Discharge point of Stormwater Drainage Pipe (9) Turtle Beach (10) Jamaica Grande Hotel (11) Fern Gully Drainage Channel (12) Town of Ocho Rios [illegible]

Figure 4-2 Eastern Ocho Rios Bay with Turtle Beach looking to the northwest Stormwater drainage pipes enter the bay at the end of the small boat pier in the foreground (1) and in the left corner of the bay adjacent to the Turtle Towers (2) *(Photograph taken by J S Tyndale-Biscoe on 30 August 1995)*

Figure 4-3 Sailor Hole Beach looking to the east The mouth of the Sailor Hole River is located just beyond the fishing boats

Figure 4-4 Sailor Hole Beach looking to the west, from the mouth of Turtle River The beach is used actively by mainly local residents for bathing at all times of the week

Figure 4-5 Turtle River 20 m from its mouth looking upstream The river flows continuously being fed in large part by groundwater springs The average flow rate was approximately 0 57 m^3/sec (20 cubic feet per second) Turtle River is the main source of faecal coliform to the Western Ocho Rios Bay and the Sailor Hole Beach

Figure 4-6 Sailor Hole River 100 m from its mouth looking downstream from Main Street Faecal coliform concentrations are high but not as high as in Turtle River The river is also partly fed by groundwater springs One of the springs (foreground) is used by the small fishing community for bathing and laundry The faecal coliform concentrations were very low or absent in the spring water during dry weather conditions sufficient wet weather data are not yet available

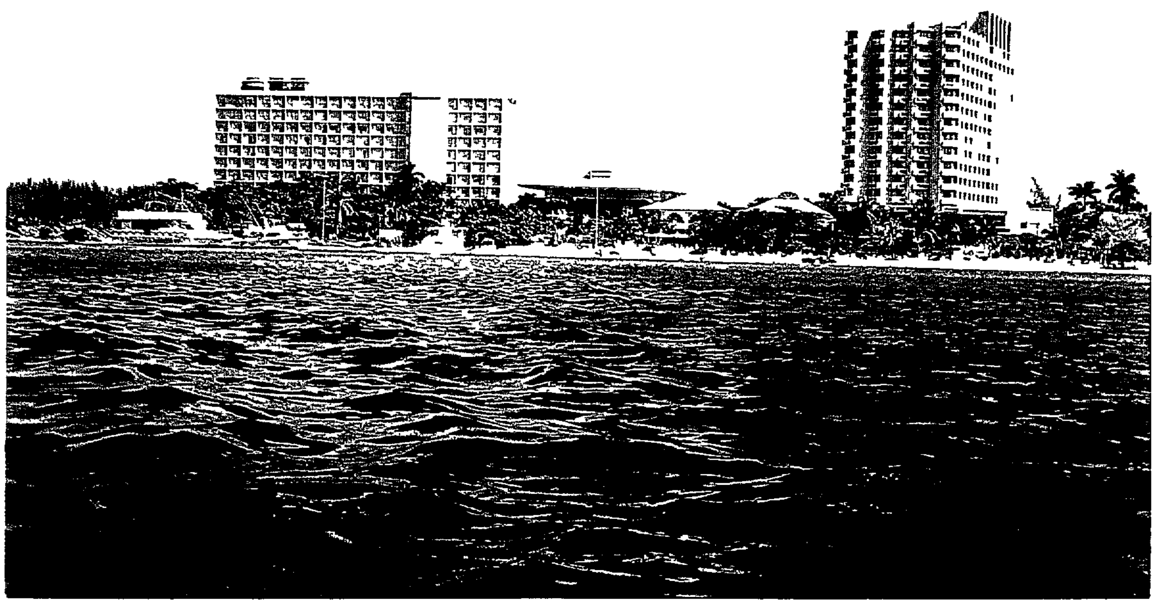

Figure 4-7 Eastern Ocho Rios Bay (looking to the east) with Turtle Beach and the two towers of the Jamaica Grande Hotel

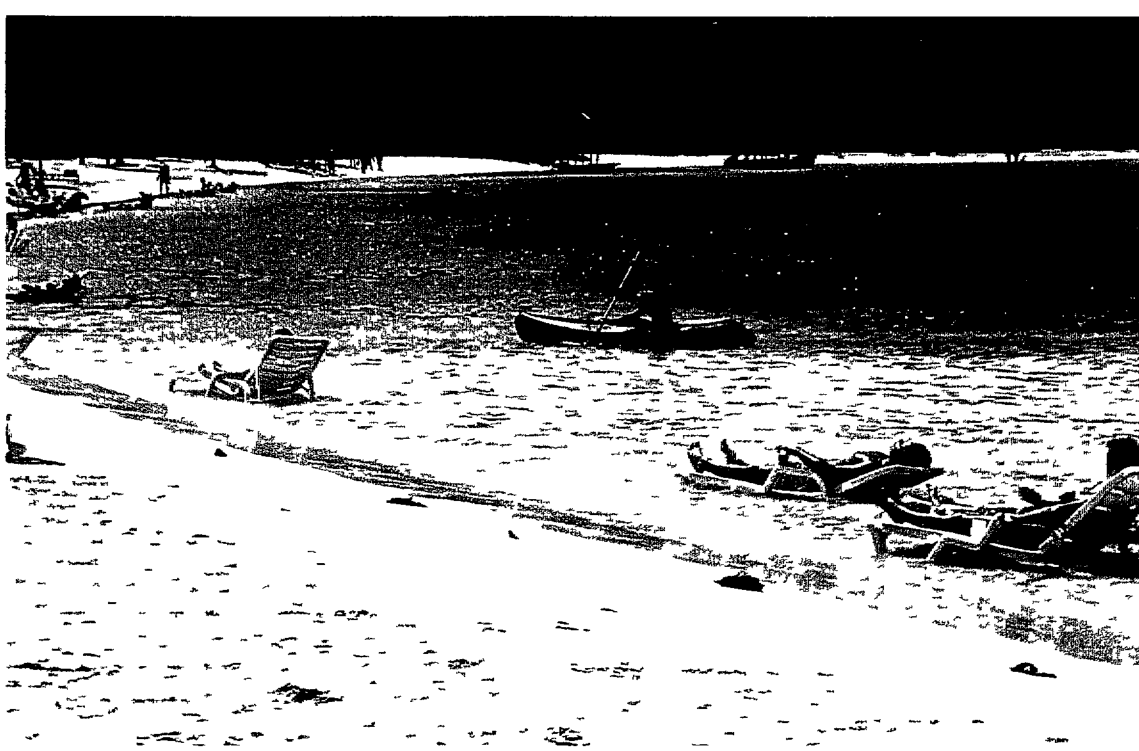

Figure 4-8 Turtle Beach The beach is used actively for recreational purposes by local residents and tourists

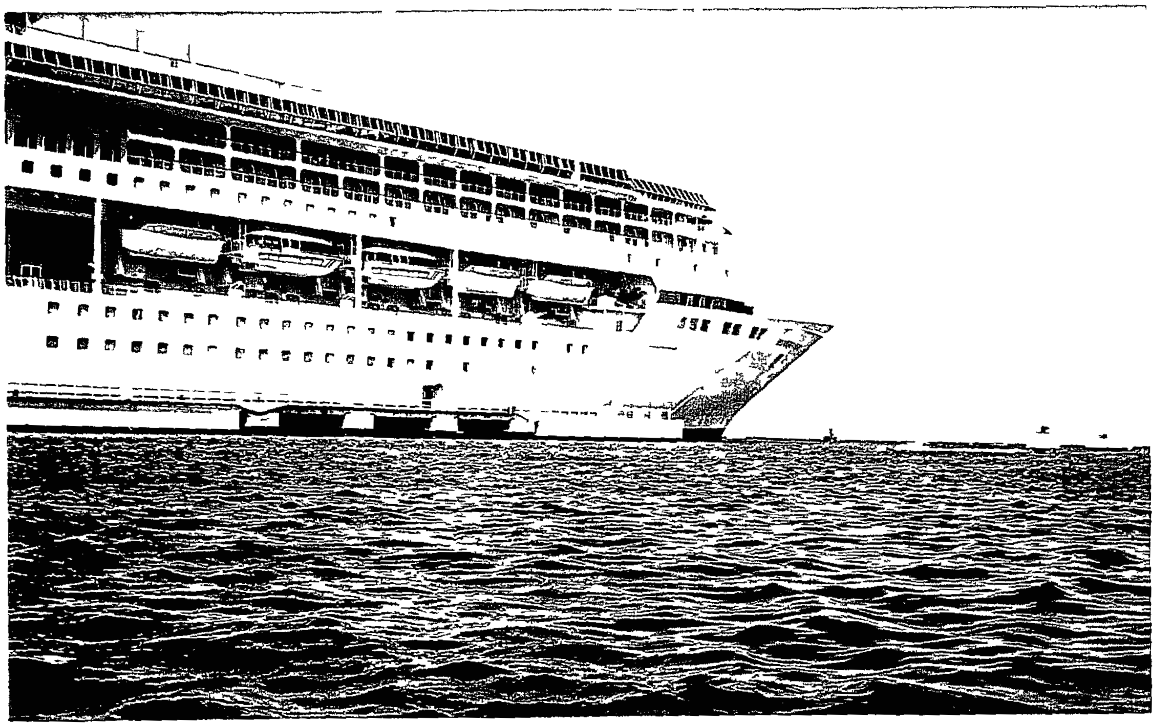

Figure 4-9 Typical cruise ship moored in Ocho Rios Bay One or two cruise ships arrive in Ocho Rios on a daily basis Recently, cruise ships apparently have not been discharging wastewater from their holding tanks into the bay, although incidents supposedly occurred in the past Zero-discharge conditions should continuously be monitored and strictly enforced

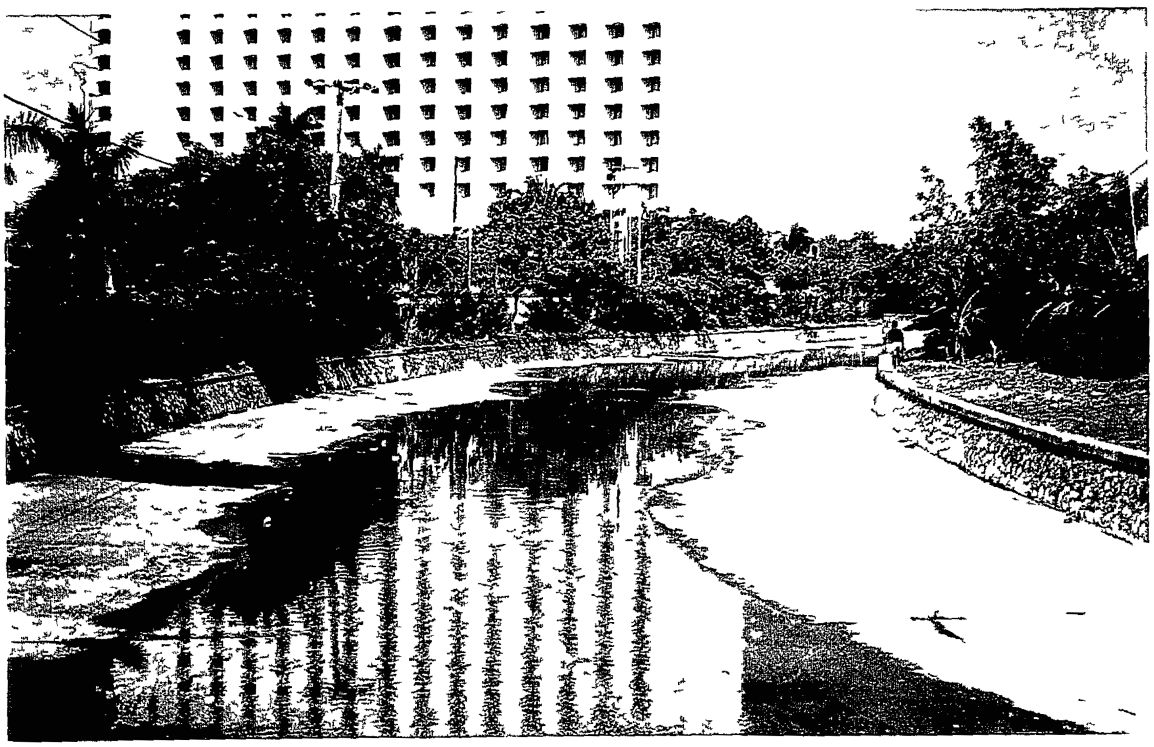

Figure 4-10 Fern Gully Drainage Channel, east of the Jamaica Grande Hotel looking downstream The flow during dry weather conditions (photo) is very low (approximately 0 03 m^3/sec or 1 cfs) the dry weather flow has no adverse impact on the beaches in Ocho Rios Bay The effect of large rainstorms has not yet been examined

Table 4-1a

Rainfall - 6 km south of Ocho Rios, 1997 (in mm)
(Location Cole Gate, Fern Gully)

Day	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1		4 1	3 3									1 0
2										9 7		
3	0 8	2 3	2 8			86 4	4 8	5 6		6 4		
4						104 1				15 0		
5	5 3		2 0			17 5					13 2	
6			8 6				0 5				1 0	
7			2 3				3 6			17 8	28 7	12 2
8		TR	3 1				1 3					
9		TR	10 7							3 6		
10				8 6					9 7			
11		5 1		20 3					11 7	3 1		
12		4 1				6 6				17 5		
13		5 6	4 6							81 0		
14		1 8							16 4	15 8		
15						17 5						8 4
16										4 8		1 5
17		2 3	20 3								28 2	
18		2 8		TR								17 3
19	1 5	8 6		5 3		5 1					3 3	10 2
20	13 7	2 8	6 9							30 7	1 3	
21	2 0	27 9					2 1			1 8		
22	1 0	8 1	6 1				5 8				41 1	
23		2 0	32 0						11 9		14 2	
24		8 1									3 6	
25		8 1	5 3									
26			15 2					1 3				
27	8 4							12 2				
28								2 5				
29												
30	4 1				70 6		0 5					
31												
Sum	36 8	93 7	123 2	34 2	70 6	237 2	18 6	21 6	49 7	207 2	134 6	50 5
No of days	8	15	14	3	1	6	7	4	4	12	9	6

Statistics for the year

Total Rainfall	1 078 mm	no data yet
Number of rain days	89 (without TR)	
Highest rainfall volume in a day	104 mm	

(Values represent rainfall between 9 00 am of the recorded day and 9 00 am of the next day TR (i e trace) represents rainfall of less than 0 1 mm)

Source Meteorological Office Kingston and Mr Drayton Ocho Rios

Table 4-1b

Rainfall in Ocho Rios, 1997 (in mm)

(Location Comfort Suites Hotel)

Day	*Jan*	*Feb*	*March*	*April*	*May*	*June*	*July*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
1											15 7	
2										22 4		
3										2 0		
4											0 7	
5											9 8	
6												
7											55 1	
8												
9												
10											1 6	
11												
12												0 33
13											0 3	
14												
15												
16												
17												
18											4 3	
19											11 1	
20											8 9	
21												
22											4 6	
23											76 1	
24											14 4	
25											0 3	
26												
27										TR		
28												
29									0 1			
30										TR		
31										0 1		
Sum											203 0	
No of days											13	

no data

(Values represent rainfall between 0 00h and 24 00h of the same day

TR represents trace amounts of rain that did not result in any readings by the gage

Source Rain gage of Louis Berger International Inc

Flow rates for the Turtle River during the rainstorm on October 2 are not available Stormwater discharge was also not observed in the Fern Gully Drainage Channel, the discharge rate during dry weather was approximately 0 03 m^3/sec (1 cfs)

4 2 3 Faecal Coliform

Data and statistical averages for each sampling event are presented in Attachment A, a summary of the data is presented in Table 4-2 and Figures 4-11 to 4-13

Turtle River During dry weather, faecal coliform concentrations in the river ranged between 1,400 and 44,000 col/100 ml with a geometric mean of 6,700 col/100 ml (28 samples) During wet weather (Oct 2, one hour after the rainstorm), the faecal coliform concentration was 194,000 col/100 ml Between individual sampling events, the highest concentrations were measured during Event 3 at the end of October, on average the concentrations were higher by a factor of 5 than the concentrations during Event 2 one month earlier (Attachment A) The reason for the higher concentrations is not known but could be related to rain earlier in the month of October (Table 4-1a)

Sailor Hole River Faecal coliform concentrations in the river ranged between 120 and 3,900 col/100 ml during dry weather with a geometric mean of 470 col/100 ml (28 samples) During wet weather (Oct 2, one hour after the rainstorm), the faecal coliform concentration was 3,500 col/100 ml The highest faecal coliform concentration was measured during Event 1 on August 26, thirty minutes after the beginning of a small rainstorm (>20,000 col/100 ml) Even though the rainstorm was short, it appeared to generate sufficient stormwater runoff The average faecal coliform concentrations between different sampling events did not differ substantially, which is probably a reflection of the steady supply of groundwater to the river

Sailor Hole Spring Faecal coliform concentrations were generally very low, ranging between 0 and 20 col/100 ml in most of the samples One sample had a concentration of 264 col/100 ml, although there is no obvious explanation for this concentration other than a one-time localized source of contamination or analytical error The sample collected one hour after the rainstorm on October 2 had a concentration of 20 col/100 ml Given the considerable flow rate in the spring, these data suggest that faecal coliform enters the Sailor Hole River further upstream in the watershed This suggestion is supported by the high faecal coliform concentration measured on October 1 at Station OR-30 (5,600 col/100 ml)

Fern Gully Drainage Channel The channel was tested only on October 1, as it was never observed carrying stormwater The concentrations in a sample collected near Main Street (OR-32) and a second sample further upstream (OR-33) were 4,000 and >11,000 col/100 ml, respectively However, without high flow rates of stormwater runoff, the channel is not a potential source for faecal coliform in Ocho Rios Bay

Western Ocho Rios Bay - Dry Weather Faecal coliform concentrations in the western bay ranged between 0 and 23,000 col/100 ml during the four sampling events Along the Sailor Hole Beach (Station OR-1), faecal coliform concentrations ranged between 0 and 890 col/100 ml during dry weather with a geometric mean of 118 col/100 ml (28 samples) Of all dry weather samples

4c

Table 4-2

Faecal Coliform Concentrations in Ocho Rios Bay *(Statistics)*

Turtle Beach and Sailor Hole Beach

SAMPLING EVENTS 2 to 4 September 28 to December 12 1997

Location		Station No	Water Depth (appr m)	FAECAL COLIFORM (col/100 ml) *(Berger samples only)*											
				Weighted Geometric Mean	Count	Minimum	Maximum	Percent of samples above 200 col/100 ml	Percent of samples above 400 col/100 ml	Weighted Geometric Mean	Count	Minimum	Maximum	Percent of samples above 200 col/100 ml	Percent of samples above 400 col/100 ml
				Dry Weather Only *(without rain samples from Oct 2 & 3)*						***All Weather*** *(incl rain samples from Oct 2 &3)*					
Sailor Hole Beach	20 m from public beach	OR 1	1 2	**94**	28	0	890	29%	18%	**118**	30	0	8 300	33%	17%
	25 m from fishermen s beach	OR 2	1 5	**94**	28	0	14 800	25%	25%	**106**	30	0	14 800	30%	17%
	western cruise ship pier	OR 4	>15	**178**	27	19	6 400	41%	41%	**209**	29	19	6 400	45%	28%
	eastern cruise ship pier	OR 5	>15	**167**	27	12	23 000	37%	33%	**203**	29	12	23 000	41%	24%
Turtle River	20 m upstream from its mouth	OR 8	0 3	**6,732**	28	1 400	44 000	100%	100%	**7 986**	30	1 400	194 000	100%	100%
	small tributary 100 m from mouth	OR 29		5	1					5	1				
	at Da Costa Drive bridge	OR 31	0 2	90	1					90	1				
Sailor Hole River	30 m upstream from its mouth	OR 6	0 3	**472**	28	120	3 900	93%	71%	**518**	30	120	3 900	93%	53%
	spring bathing area for fishermen	OR 24	0 2	**2**	18	0	264	6%	6%	**3**	20	0	264	5%	0%
	confluence with spring water	OR 28	0 2	170	1					170	1				
	laundry mat discharge basin	OR 30	0 1	5 600	1					5 600	1				
Turtle Beach	west near Sand Castles	OR 9	3 0	**10**	28	0	600	4%	4%	**12**	30	0	600	3%	3%
	east near Renaissance Hotel	OR 11	2 1	**6**	28	0	180	0%	0%	**7**	30	0	1 600	3%	3%
	center beach	OR 12	2 0	**8**	28	0	720	11%	11%	**9**	30	0	720	10%	3%
	central bay 100 m from shore	OR 13	10 0	**10**	28	0	530	11%	7%	**12**	30	0	530	17%	7%
	beach north of groin	OR 14	3 0	**3**	27	0	130	0%	0%	**3**	29	0	130	0%	0%
	10 m off groin	OR 20	>15	**5**	28	0	540	7%	4%	**7**	30	0	2 700	13%	7%
	entrance to boat harbour	OR 21		**23**	28	0	270	7%	4%	**27**	30	0	4 000	10%	3%
	end of boat pier	OR 22		**105**	28	0	17 900	32%	32%	**127**	30	0	17 900	37%	33%
	50m seaward from end of boat pier	OR 23		**8**	28	0	640	7%	7%	**10**	30	0	1 200	10%	10%
	center of boat harbour	OR 25		40	1					40	1				
	125m seaward from end of boat pier	OR 26		**10**	23	0	120	0%	0%	**13**	25	0	680	4%	4%
	eastern end of cruise ship landing	OR 27		**10**	22	0	123	0%	0%	**14**	24	0	610	8%	4%
Fern Gully channel	downstream at Main Street bridge	OR 32	0 05	4 000	1					4 000	1				
	upstream at Shell gas station	OR 33	0 05	11 000	1					11 000	1				

Not available or not applicable

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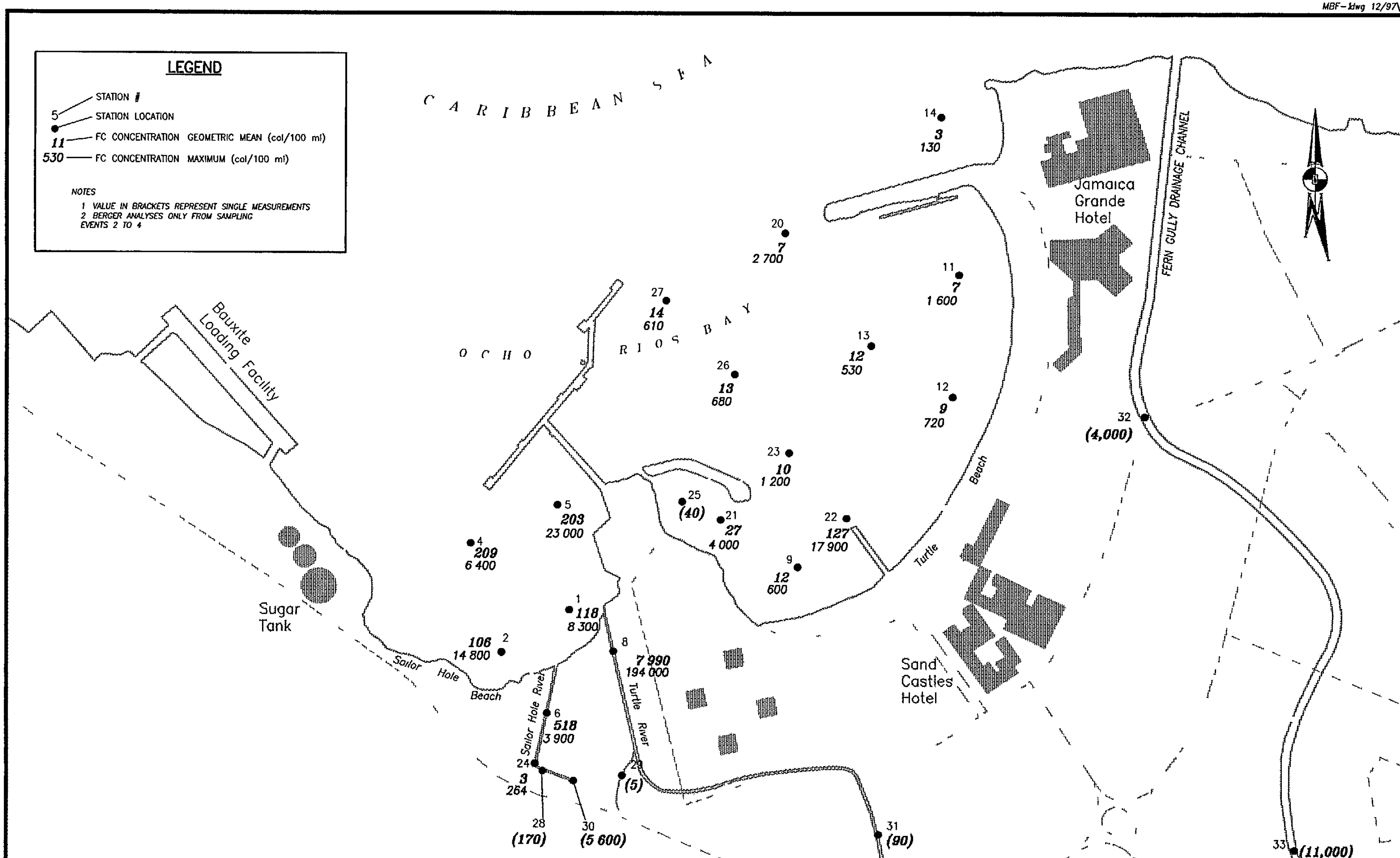

US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure 4-11
LOUIS BERGER INTERNATIONAL, INC	Approximate Scale 1cm = 120 meters	OCHO RIOS - Faecal Coliform (Concentrations)
Technical Support Services, Inc	December 1997	Sept 28 to Dec 12, 1997 All Samples

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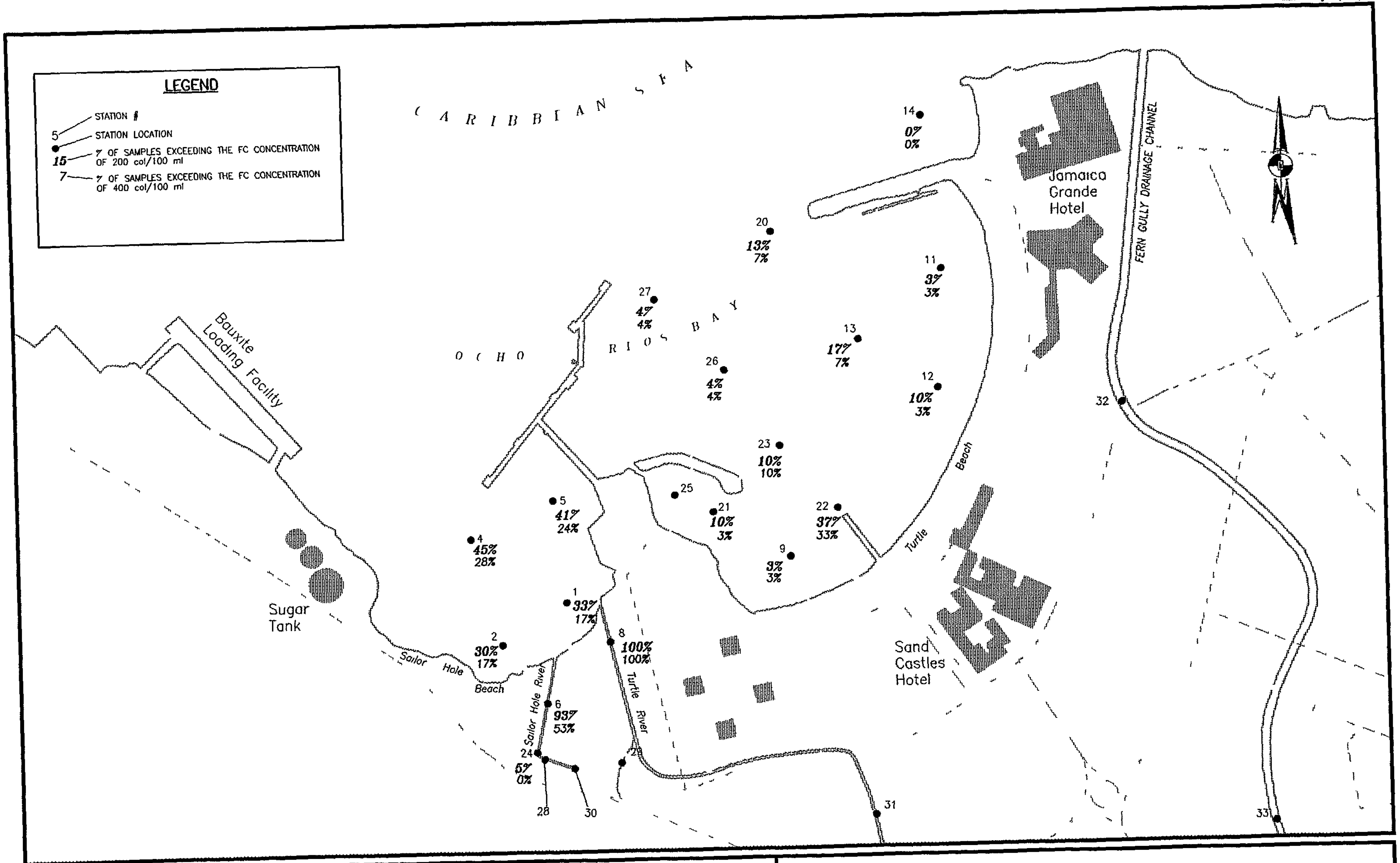
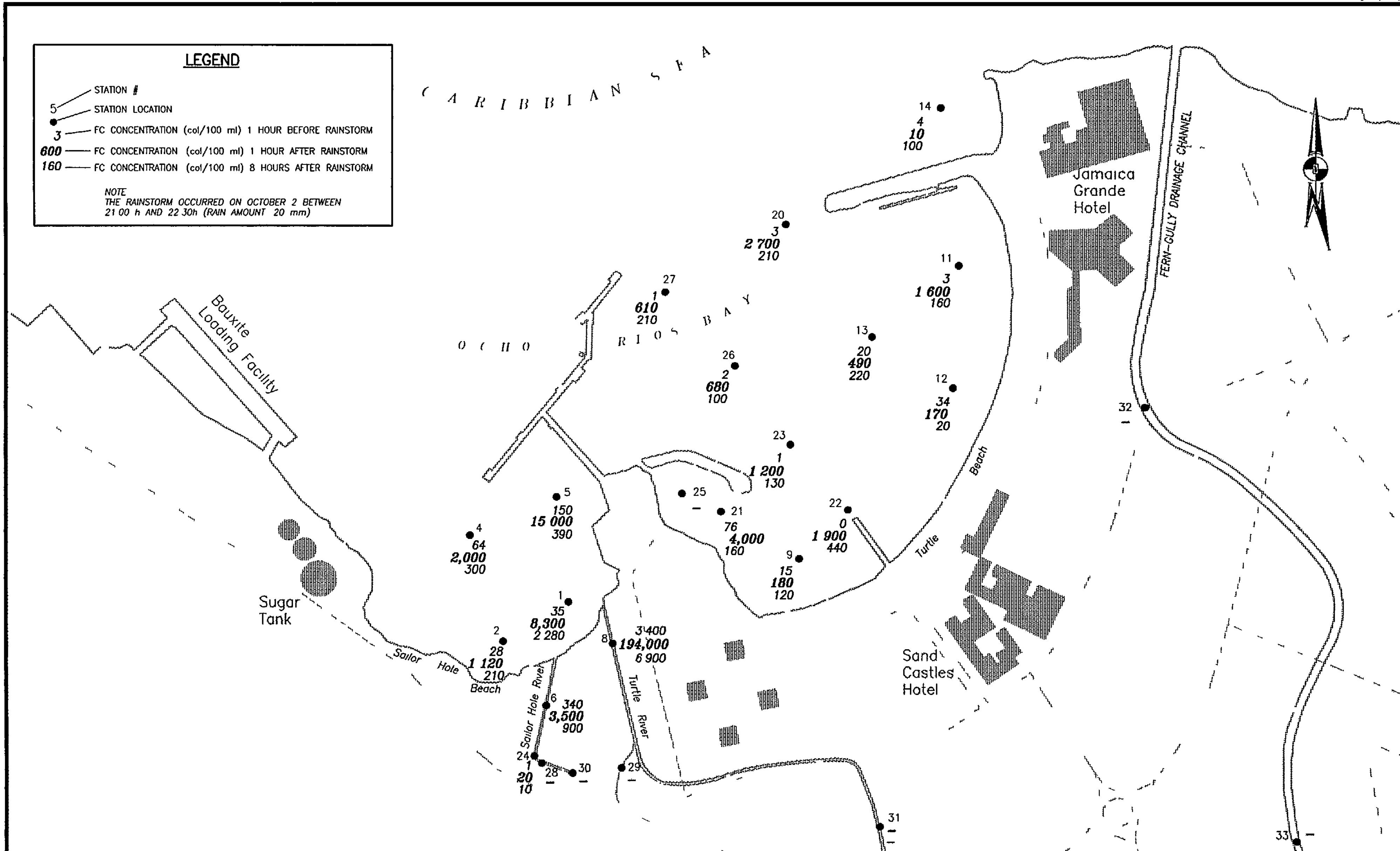


US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure 4-12
LOUIS BERGER INTERNATIONAL, INC	Approximate Scale 1cm = 120 meters	OCHO RIOS - Faecal Coliform (% Exceedence)
Technical Support Services, Inc	December 1997	Sept 28 to Dec 12, 1997 All Samples

MBF-3 dwg 12/97\A.G



US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure 4-13
LOUIS BERGER INTERNATIONAL, INC Technical Support Services, Inc	Approximate Scale 1cm = 120 meters	OCHO RIOS - Faecal Coliform (Concentrations) Effect of Rainstorm on Oct 2, 1997
	December 1997	

analyzed at Station OR-1, a total of 29% of the samples exceeded the USEPA standard of 200 col/100 ml (Figure 4-12) The faecal coliform concentrations at the two stations further offshore (OR-4,5) were generally higher than the concentrations at the two stations closer to shore (OR-1,2), most likely reflecting the movement of the coliform-laden Turtle River water in the bay

Eastern Ocho Rios Bay - Dry Weather Faecal coliform concentrations at all stations in the eastern bay (except for the Station OR-22, drainage pipe) ranged between 0 and 720 col/100 ml during dry weather conditions with geometric means between 3 and 23 col/100 ml (28 samples per station) Concentrations within the entire eastern bay were comparatively similar, reflecting limited exchange of water with the open ocean At Station OR-22 at the end of the drainage pipe, the dry weather faecal coliform concentrations were higher by roughly an order of magnitude, ranging between 0 and 17,900 col/100 ml with a geometric mean of 105 col/100 ml Of all dry weather samples analyzed in the eastern bay, between 0% and 11% of the samples exceeded 200 col/100 ml (Figure 4-12) At Station OR-22 a total of 32% of the dry weather samples exceeded 200 col/100 ml

Western and Eastern Ocho Rios Bay - Rainstorm on October 2 One hour after the rainstorm in the evening of October 2, the faecal coliform concentrations at most stations were higher than one hour before the rainstorm by one to two orders of magnitude (Figure 4-13) The concentrations at most stations greatly exceeded the USEPA standard of 200 col/100 ml Along Sailor Hole Beach, the faecal coliform concentration was 8,300 col/100 ml In the Turtle Beach area, the concentrations ranged between 170 and 4,000 col/100 ml The concentrations in Turtle River and Sailor Hole River were well above the maximum concentrations measured during dry weather conditions Eight hours after the storm, the faecal coliform concentrations had declined, but were still above the mean dry weather concentrations Specifically, in the western Ocho Rios Bay area, the faecal coliform concentrations still exceeded the USEPA standard at all stations, in the eastern bay, the concentrations were either at or below the USEPA standard with the exception of Station OR-22 (end of boat pier) where the concentration was still 440 col/100 ml The only notable exception to this pattern was Station OR-14, located north of the groin of the Jamaica Grande Hotel The faecal coliform concentration one hour after the storm had not increased substantially, but was higher eight hours after the storm The delayed increase was likely caused by the delay in diffusion of water from the Fern Gully drainage channel and from the Ocho Rios Bay

4 3 Discussion

4 3 1 Western Ocho Rios Bay

The main sources for faecal coliform for the western Ocho Rios Bay is the Turtle River The second source is the Sailor Hole River Based on the average flow rates for these two rivers and their average faecal coliform concentrations of 8,000 and 520 col/100 ml, respectively (Table 4-2), the Turtle River contributes approximately 98% of the faecal coliform load to the western bay, while the Sailor Hole River contributes 2% Additional coliform sources could be groundwater seepage in coastal waters, although seepage is expected to be a minor source to the bay

The freshwater from the Turtle River spreads throughout the entire western bay including the Sailor Hole Beach The concentrations at the two stations further offshore were higher than the

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concentrations of the two nearshore station suggesting that the river water fans out after entry into the bay However, the pattern was not consistent

The dry weather concentrations along the Sailor Hole Beach were one third of the time above the USEPA standard of 200 col/100 ml The data did not reveal an obvious pattern but higher dry weather concentrations may exist after prolonged periods of rain This is suggested by the generally higher concentrations in the river and the western bay during Events 3 and 4 Heavy rains preceded the weeks before Event 3 a rainstorm occurred in the Turtle River watershed on the first day of Event 4 It is conceivable that a higher groundwater table in the watershed results in increased leaching of coliform sources Assuming that this reasoning is correct, faecal coliform concentrations during drier months should be lower than during rainier months

The wet weather concentrations along the Sailor Hole Beach area were only measured once However, given that the dry weather concentrations are already close to the USEPA standard, and that the measurements during the single storm were well above the standard, it is reasonable to assume that the faecal coliform concentrations along the beach are high during and after most, if not all, storms with significant runoff within the watershed of the Turtle River The length of high concentrations in the bay after a storm depends on the length of the storm and the rain volume, as well as on the water exchange rate of the bay water with the open ocean Based on the data from the October 2 storm, the faecal coliform concentrations 8 hours after the storm were still considerably higher than one hour before the storm (Figure 4-13)

4 3 2 Eastern Ocho Rios Bay

The main source of faecal coliform to the eastern Ocho Rios Bay appears to be the stormwater drainage pipe that extends into the southern part of the bay underneath the boat pier A second pipe is entering the bay near Turtle Towers Other potential sources consist of discharges by small boats moored along the fringes of the bay, cruise ship discharges, discharges by the Fern Gully Drainage Channel, and from the sewage treatment plant along the hill Each of these sources is discussed in more details below

The pipe underneath the boat pier drains stormwater from the Town of Ocho Rios It enters the bay at the end of the boat pier at a depth of approximately 4 m The pipe has a diameter of approximately 0 5 meters The distinctly higher faecal coliform concentrations at Station OR-22 as compared to other stations in the bay shows that faecal coliform is also entering the eastern bay through this pipe during dry weather conditions (Attachment A) The origin of the sources that discharge during dry weather is not known, but is presumed to be smaller sewage line connection Conditions during a rainstorm were not observed, measurements one hour after the October 2 rainstorm showed generally high concentrations in the general area of the pipe as a result of dilution Residents in the area stated that during rainstorms the freshwater running through the pipe can be seen upwelling at the end of the pier Also, the eastern bay may fill with brownish-colored water

The wastewater discharged through the pipe also contains oil at times, as indicated by the oil within the sediment in the vicinity of the mouth of the pipe The sediment was collected through sediment cores

Information about the second pipe, located adjacent to the Turtle Tower, is not available The pipe appears to be draining stormwater from parking areas Residents told us that laundry detergents have been seen entering the bay from the pipe, but such observations were not made during our sampling activities The relevance of the second pipe for the water quality in the bay needs to be examined more closely during rainstorms

Cruise ships could represent a large point source of faecal coliform to the bay, although discharges were not observed during our sampling activities Cruise ships were in port during several of the sampling days and illegal discharges would have been detected in our faecal coliform data It appears from talking to residents that cruise ship discharges have not occurred in the recent past

Small boats are moored in three locations in the eastern Ocho Rios Bay the small harbor to the west, the boat pier near the Sand Castles Hotel, and the boat pier along the groin adjacent to the Jamaica Grande Hotel According to residents, people live on some of the boats Clearly, sewage containers and facilities should not be emptied into the bay, although any potential discharges from these facilities are expected to be comparatively small A more important contribution by boats to the water quality in the bay is made by discharges of motor oil and oily bilge water into the sea

The Fern Gully Drainage Channel is not a source to the Ocho Rios Bay during dry weather During large rainstorms the channel could potentially be a source, if the river water gets diverted to the west upon entry into the ocean and then transported into the bay However, the dynamics of the river water entering the ocean during rainstorms is not clear based on discussions with several residents

The ocean outfall of the existing sewage treatment plant is located to the east of the bauxite loading facility The distribution of the faecal coliform data suggest that the pipe is not a source to the eastern Ocho Rios Bay and most likely also not to the western bay

4 3 3 Sailor Hole Spring

The Sailor Hole Spring at the entrance to the small fishing village is used by the fishing community for bathing and laundry The low faecal coliform concentrations show that the water is safe for these activities Conversations with members of the fishing community indicated that the water is occasionally also used for drinking (without boiling) However, drinking of the water is not recommended, as the measured concentrations exceed both the USEPA and World Health Organizations standards for drinking water

4 4 Recommendations

4 4 1 Western Ocho Rios Bay

4 4 1 1 Water Quality Improvements along the Turtle River

Improving the water quality of the Sailor Hole Beach requires improving the water quality of the Turtle River Improvements will be a slow process A water quality study of the Turtle River

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conducted by the Water Resources Authority in Jamaica in 1994 concluded that the water in the river receives leachate from pit latrines and adsorption pits The water apparently travels between the thin top soil and the low-permeability rock formation underneath In addition, surface discharge pipes were observed that carry wastewater from premises along the river It is currently not which source predominates

Aside from improving the water quality of the Sailor Hole Beach, improving the water quality in Turtle River would also be beneficial for other users

- Residents from Ocho Rios regularly use the water in the river for washing and bathing near the bridge over the La Costa Drive Given the high faecal coliform concentration in the river this activity is presently not recommended, specifically after rainstorms Improved water quality of the river water would reduce health risks

- The river is used by tourist establishments for various recreational purposes along its course

Activities toward improving the water quality of the river requires identifying the main sources for coliform and eliminating them to the extent feasible In addition, all larger establishments with adsorption pits as well as residences should be connected to the new wastewater sewage system in the town, if feasible Priority should be given to remediate any direct discharges as they have a disproportionately higher impact than other sources

Further, we recommend to build on the study by the Water Resources Authority (WRA, 1994) with additional sampling in order to track down specifically the main sources for faecal coliform in the river The WRA study was based on 2 sampling days with 6 faecal coliform measurements during each day We recommend to conduct additional sampling with a higher sample density along the river Samples should also be collected during dry weather and wet weather conditions At the same time, the river should be inspected in detail in order to locate every pipe that enters the river

Removing some of the sources for faecal coliform to the river may not remove all sources, but it should be possible to reduce the coliform concentrations sufficiently to allow for swimming along Sailor Hole Beach during dry weather conditions

4 4 1 2 Beach Management

Currently the water quality at the beach is poor Faecal coliform concentrations along the Sailor Hole Beach exceeded the USEPA standard for bathing 29% of the time during dry weather conditions During the single rainstorm in the study period, the faecal coliform concentrations were 40 times above the standard

Until the water quality of the river is improved, appropriate management steps should be taken by local authorities to inform the public about the risks at the beach Swimming should specifically be avoided during and after large rainstorms

In addition, drinking of untreated or unboiled water and washing of food in the Turtle River and the Sailor Hole River presents a clear health risk at all times, and thus should be avoided

4 4 2 Eastern Ocho Rios Bay

4 4 2 1 Water Quality Improvements through Removing the Discharge from the Drainage Pipe

The main source of coliform to the eastern Ocho Rios Bay is the stormwater drainage pipe underneath the boat pier During wet weather conditions, the pipe appears to be the main source of contamination of the bay This pipe appears to be discharging wastewater also during dry weather conditions

Mitigation of wastewater entering the bay through the pipe during dry weather conditions requires locating and disconnecting direct wastewater discharges from households and other establishments that currently enter the stormwater drainage pipes Connections should instead be established to the new sewage treatment plant

However, stormwater discharges will most likely still carry high loads of coliform into the bay due the multitude of small point and non-point sources Most likely, the only effective mitigation measure for maintaining safe bathing conditions along the beach during wet weather is the relocation of the stormwater drainage pipe One options consists of extending the pipe out to sea beyond the reef The second option consists of rerouting the discharge point to the east into the Fern Gully Drainage Channel This option may require pumping

If the pipe will be relocated or extended, it may be worthwhile to include the second stormwater drainage pipe at the same time At this time, the contribution of faecal coliform to the bay from the bay is not yet known and should be investigated to determine if the pipe is a significant source of pollution as well Such data are planned to be collected as part of additional activities suggested in Section 4 5 below

4 4 2 2 Beach Management

Given the active use of the beach and its economic importance to the town, we highly recommend to develop a management plan that addresses the issue of high faecal coliform concentrations during rainstorms This management plan should develop an approach to close the beach (for water contact activities only) for certain periods after rainstorms The size of the storm (in terms of volume of rain) and the period of closure after a storm (in terms of hours) still needs to be determined with additional data Fortunately the preliminary data suggest that only short periods of closure may be necessary The management plan needs to be developed in close coordination with national and local authorities, given the sensitivity of the issue Removing the main source would likely render closure unnecessary or reduce their frequency to only the largest rainstorms

The management plan should also include issues regarding the use of boats in the eastern Ocho Rios Bay Pollution caused by the boats at present (such as motor oil and bilge water spills) are largely avoidable Existing boat maintenance regulations should be reviewed for small boats and be enforced At the same time, local authorities should create facilities on shore to facilitate easy compliance by the boat owners with such regulations Such facilities include receptacles for motor oil and bilge water, as well as receptacle for sewage and solid waste that accumulates on these boats These facilities should be maintained, costs for maintenance could be covered by license fees

4 5 Suggested Activities for Development of Beach Management Plan

As part of this project we recommend the following activities toward the goal of safe swimming conditions along the Sailor Hole and Turtle Beaches

- *Additional Sampling - Western Ocho Rios Bay* For the western bay, there are sufficient data available to understand the beach water quality Additional data would be useful after rain events but faecal coliform concentrations are expected to be high based in the existing information The rain event needs to focus on the time required for the 'recovery' of the bay waters as this is essential information for any beach management plan Equally important is the need for additional data for the identification of faecal coliform sources in the Turtle River watershed

- *Additional Sampling - Eastern Ocho Rios Bay* For the eastern bay, additional faecal coliform data for wet weather conditions are crucial for the development of a meaningful beach management plan Currently, the water quality along Turtle Beach during dry weather is adequate for swimming most of time, but deteriorates during rainstorms Open questions are as follows

  - How much rain is needed during a storm to decrease the water quality to below swimming standards?

  - How many hours does it take after a rainstorm before the water quality has improved through dilution and die-off to again be suitable for swimming?

- *Additional Sampling - Fern Gully Drainage Channel* Wet weather samples are needed also from the Fern Gully Drainage Channel and the area of the ocean surrounding the mouth of the channel to assess whether the channel is a source to the Ocho Rios Bay The freshwater plume of the river upon entry into the bay should be observed visually and with a salinity meter to determine the direction of flow

- *Other Pathogen Indicators* During our sampling events, tests were also conducted for enterococcos as another bacterial indicator for human health These data are currently still being synthesized We plan on processing these data further and comparing them with the faecal coliform results as a second indicator for pathogens

- *Rainfall Analyses* As part of the management plan existing historic rainfall data should be analyzed for as long a historic time period as data exist The goal of this analysis is to determine the typical size of a rainstorm and the frequency of occurrence throughout the year

This information would become part of the management plan, and would allow for calculation of the frequency of any temporary beach closure

- *Investigation of Stormwater Drainage Pipe* The stormwater drainage pipe should be reviewed Information needed is the area of contribution to the pipe and potential connections At an advanced stage it may be advisable to conduct dye studies to trace wastewater connections of residences or other establishments These are routinely conducted for identification of direct sewage discharges in U S coastal regions

5.0 MONTEGO BAY - Walter Fletcher Beach

5 1 Overview

Walter Fletcher Beach is located in the City of Montego Bay (Figure 5-1) The beach borders the eastern side of Montego Bay (the water body) It was artificially created through filling of shallow coastal lands in recent years The beach is in the middle of a string of three beaches with Dump-up Beach to the south and One-man Beach to the north (Figure 1-3) Each beach is partially protected from the ocean by a rock groin structure

Walter Fletcher Beach is fenced and has only one access point The beach is accessible to any resident or visitor for a fee of J$50 and is open between 9 00h and 22 00h The beach is actively used (Figure 5-2) Facilities along the shore of the beach consist of a small restaurant and bar, sanitary facilities, and changing rooms A few glassbottom boats are moored in the northern corner of the beach

Dump-up Beach and One-man Beach are not fenced and open to the public None of these two beaches have facilities along the shore

The closest freshwater source to these beaches are two stormwater drainage pipes that enter Montego Bay at the two groin structures located on both sides of Walter Fletcher Beach (Figure 5-3), and North Gully which enters Montego Bay just south of Dump-up Beach (Figure 5-4)

5 2 Data

5 2 1 Rainfall

Most of the samples were collected during dry weather conditions Rainfall only occurred on the day before the August 28 and the October 3 samples (Tables 5-1a and 5-1b)

August 28 A comparatively large rainstorm occurred on August 27, resulting in 23 mm of rain, as measured at the airport The rain fell in the afternoon, resulting in closure of Walter Fletcher Beach for the evening The reason provided for the closure was floating debris along the beach

October 3 An 'average' rainstorm occurred on October 2 Rain fell in Montego Bay between 19 00h and 20 00h The recorded rainfall at the Sangster International Airport was 12 mm, our gage deployed at the NWC laboratory in Bogue recorded 9 mm

5 2 2 Flow Rates

The closest surface water body that could potentially influence Walter Fletcher Beach and Dump-up Beach are North Gully and the stormwater drainage pipes North Gully, however, only has significant flow during rainstorms During dry weather the flow rate was very low (approximately 0 014 m^3/sec or 0 5 cfs) Information about the stormwater runoff in the gully during the two rain

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Figure 5-1 Eastern Montego Bay (the water body) with three crescent shaped beach areas looking to the southwest Key (1) Montego Bay (2) One-man Beach (3) Walter Fletcher Beach (4) Dump up Beach (5) North Gully (6) South Gully (7) Montego River (8) Stormwater drainage pipes (9) Gloucester Avenue (10) Downtown Montego Bay
(Photograph taken by J S Tyndale Biscoe on 30 May 1996)

Figure 5-2 Walter Fletcher Beach looking to the south The beach is used actively by mainly local residents as well as tourists

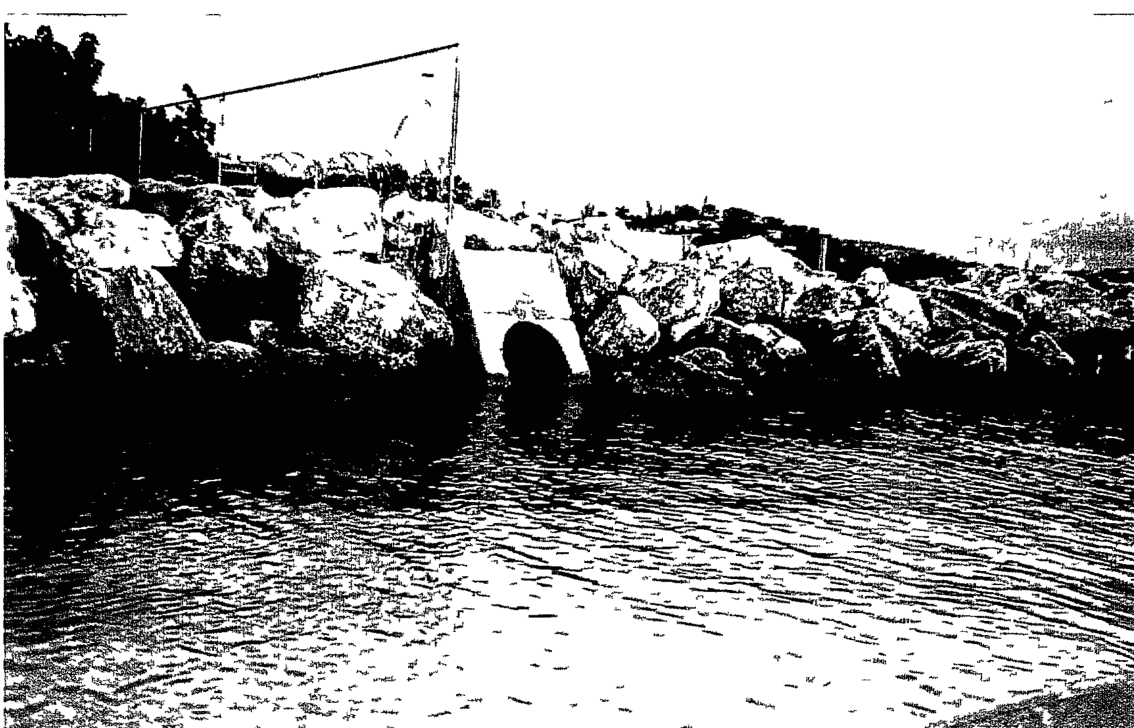

Figure 5-3 Stormwater drainage pipe entering Montego Bay in the center of the groin structures on both sides of the crescent shaped Walter Fletcher Beach

Figure 5-4 Dump-up Beach North Gully is entering Montego Bay just beyond the beach The flow in the gully is low during dry weather conditions (approximately 0 015 m^3/sec or 0 5 cfs), but is sufficient to result in high faecal coliform concentrations at the mouth of the gully During rastorms the flow rate in the gully is much higher resulting most likely in high loads of faecal coliform to the bay (wet weather data are not yet available however) Along Dump-up Beach the faecal coliform concentrations during dry weather conditions were consistently very low indicating that the rock groin provides an adequate barrier from North Gully water Conditions along the beach after large rainstorms could not yet be investigated due to the absence of rain

Table 5-1a

Rainfall in Montego Bay, 1997 (in mm)

(Location Sangster International Airport)

Day	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1	0 4							4 0	4 7	TR		0 2
2			TR			0 2			TR	11 9		
3	TR	TR	TR			8 2	TR		21 2	9 4		0 1
4		TR	TR			31 0	TR		0 3	0 5	1 0	
5	0 2			TR		4 3				3 6	0 5	0 4
6										74 8		
7						7 6			16 5	2 2	9 7	2 0
8			TR	TR		6 0	4 0					
9			1 1			0 1	0 7	3 5	4 3	74 6		
10			5 3		0 2			TR	5 2	1 6		
11		TR						TR	24 7	TR		
12	10 0			TR	TR	1 1				TR		
13						TR		0 2		43 8		
14		TR	1 3			TR	TR		TR	39 2		
15	TR		0 1			TR			10 7	2 7		
16					1 3		TR		0 6		17 2	
17	2 8		4 4		TR				2 3	1 4		
18			2 7	2 1								
19					2 4				TR	TR	2 2	
20		TR				3 8	TR	2 8			2 3	
21			TR			TR	TR				2 0	
22	1 1						2 4		TR			
23									3 1			
24				6 2		0 8			TR		1 9	
25		0 5										
26						TR		TR				
27	0 7							23 2				
28								1 3	0 2			
29	0 1				0 4			0 4				
30					9 0		14 6	0 4				
31	TR				4 0							
Sum	15 3	0 5	14 9	8 3	17 3	63 1	21 7	35 8	93 8	265 7	36 8	2 7
No of days	7	1	6	2	6	10	4	8	12	12	8	4

Statistics for the year no data yet

Total Rainfall 576 mm

Number of rain days 80 (without TR)

Highest rainfall volume in a day 75 mm

(Values represent rainfall between 7 00 am of the recorded day and 7 00 am of the next day TR (i e trace) represents rainfall of less than 0 1 mm)

Source Meteorological Office Sangster International Airport Montego Bay

Table 5-1b

Rainfall in Montego Bay, 1997 (in mm)

(Location NWC Facility in Bogue)

Day	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1										8 8		
2										0 8		0 4
3										0 2	0 4	3 0
4												
5										36 8	4 7	
6										34 4		
7										2 0		2 4
8												
9										30 0	2 5	
10										0 8		
11												
12										8 7	4 8	
13										9 2		
14										6 2	2 8	
15												
16										0 6		
17										0 9	33 4	
18												
19											2 9	
20											4 7	
21												
22												
23											0 1	
24												
25												
26												
27												
28												
29									0 9			
30												
31												
Sum									0 9	139 4	56 3	5 8
No days										14	10	

(Values represent rainfall between 9 00 am of the recorded day and 9 00 am of the next day

No data

Rain fell over two days no exact time period known

Source Raingage deployed at the NWC facility in Bogue

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days (August 27 and October 2) is not available In the Montego Bay Environmental Monitoring Programme report (Berger, 1996), the 'average' stormwater flow in North Gully was estimated between 1 5 and 5 m^3/sec (53 and 176 cfs) The worst annual rainstorm was estimated with roughly 20 to 50 m^3/sec (700 and 1,750 cfs), which is more than 1,000 times higher than the dry weather flow rate

Discharge rates for the two stormwater drainage pipes in the groins adjacent to the beach are currently not known

5 2 3 Faecal Coliform

Most of the samples were collected from the Walter Fletcher Beach area Additional samples were collected from the Dump-up Beach, and the mouth of the North Gully During Sampling Event 4, two samples were collected also from the One-man Beach, located just north of the Walter Fletcher Beach Data and statistical averages for each sampling event are presented in Attachment B, a summary of the data is presented in Table 5-2 and Figures 5-5 to 5-7

North Gully

Samples were collected from the mouth of North Gully At this station (MB-15), the inflowing gully water (freshwater) is already well mixed with the water from Montego Bay (salt water) The average salinity of the water at station MB-15 was 33 5 ppt, the salinity of Montego Bay water was 35 ppt, indicating that the gully water was already diluted approximately 20-fold with bay waters Even after dilution, the faecal coliform concentrations at this station ranged between 3,200 and 58,000 col/100 ml, clearly well above the USEPA standard Concentrations during a rainstorm are not available, but concentrations are expected to be higher than the dry weather concentrations because of a lower degree of mixing with sea water The geometric mean faecal coliform concentrations in undiluted gully water collected 200 m upstream from its mouth was measured during the Montego Bay Environmental Monitoring Programme at 350,000 col/100 ml, ranging between 54,000 and several million col/100 ml (dry weather flow only)

Beaches - Dry Weather Conditions

Walter Fletcher Beach - all data except for August 28 and October 3 27 and 28 During 'typical' dry weather conditions, the faecal coliform concentrations along the Walter Fletcher Beach were low, reflecting safe swimming conditions (Table 5-2, Figure 5-5) With the exception of October 27 and 28, faecal coliform concentrations along Walter Fletcher Beach (Stations MB-1 to 7) never exceeded the USEPA standard of 200 col/100 ml, the highest value was measured on August 26 with 60 col/100 ml

Walter Fletcher Beach - October 27 and 28 Faecal coliform concentrations on Walter Fletcher Beach on October 27 were very high exceeding 6,000 col/100 ml at several of the stations along the beach (Figure 5-3) High values were obtained by both the NWC and our laboratory Twenty-four hours later, the faecal coliform concentrations were still high along the beach reaching up to 940 col/100 ml, the quality control sample analyzed by the NWC similarly had a high concentration of

Table 5-2

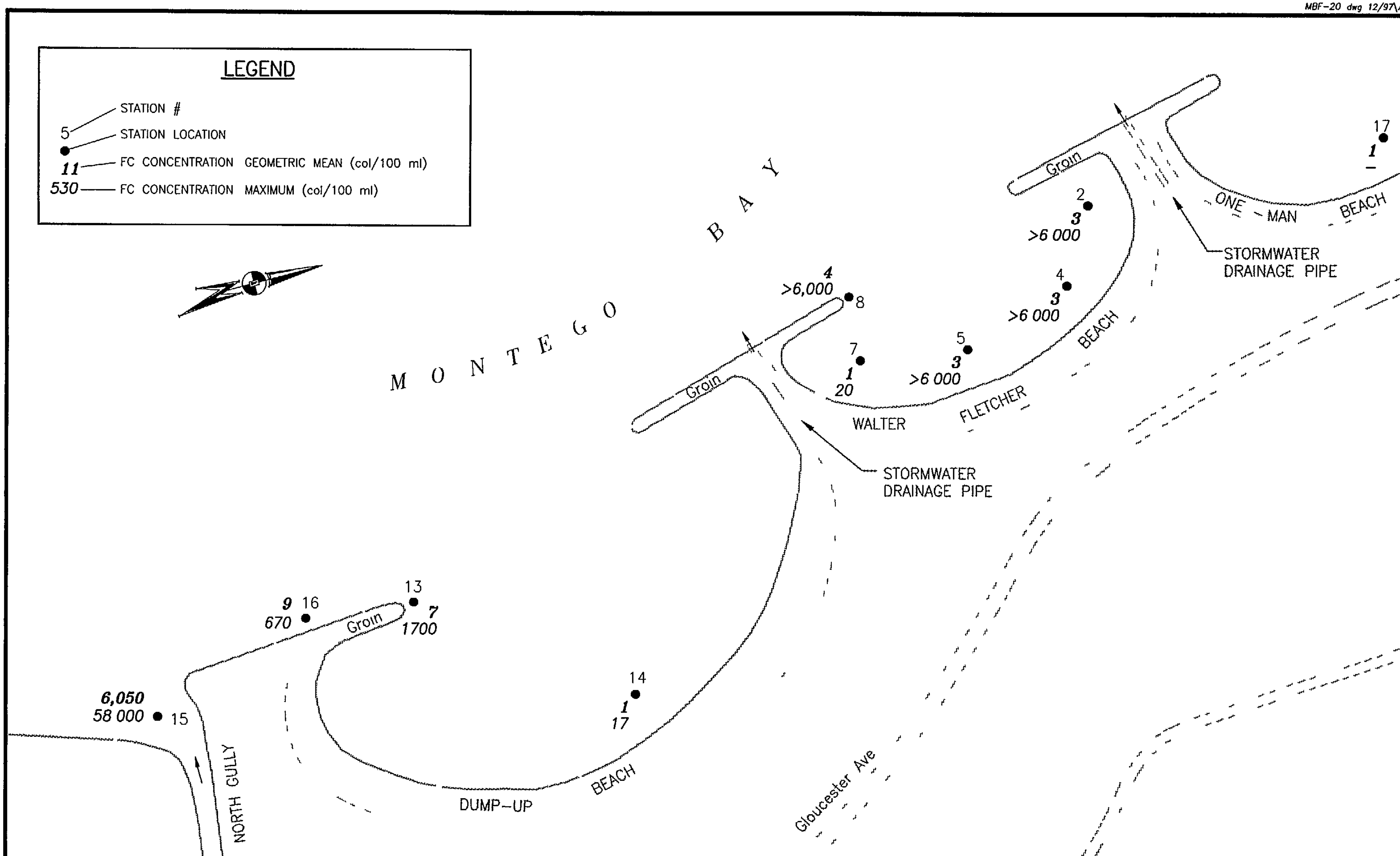
Faecal Coliform Concentrations in Montego Bay *(Statistics)*

Walter Fletcher Beach

SAMPLING EVENTS 2 to 4 September 28 to December 12 1997

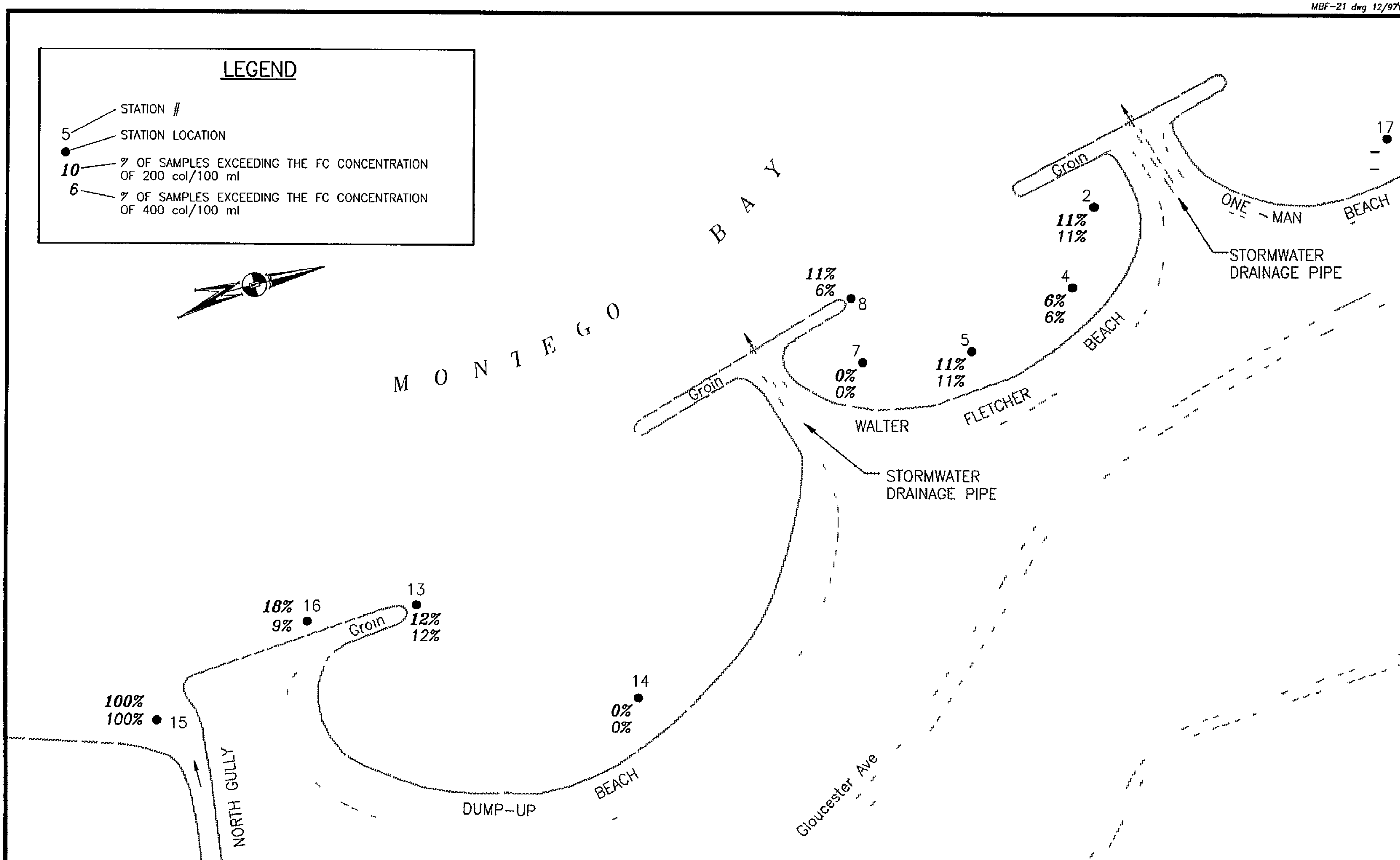
Location		Station No	Water Depth *(appr m)*	FAECAL COLIFORM (col/100 ml) *(All Berger samples & NWC samples from Oct 3 and 31)*									
				Weighted Geometric Mean	Count	Minimum	Maximum	Weighted Geometric Mean	Count	Minimum	Maximum	Percent of samples above 200 col/100 ml	Percent of samples above 400 col/100 ml
				All Samples (except high values on Oct 27 & 28)				*All Samples (incl high values on Oct 27 & 28)*					
Walter Fletcher Beach	northern corner	MB 2	1 1	**1**	16	0	37	**3**	18	0	>6 000	11%	11%
	center north	MB 4	1 6	**2**	16	0	22	**3**	18	0	>6 000	6%	6%
	center south	MB 5	1 6	**2**	16	0	12	**3**	18	0	>6 000	11%	11%
	southern corner	MB 7	1 0	**1**	16	0	10	**1**	18	0	20	0%	0%
	at southern groin entrance to beach	MB 8	0 3	**2**	16	0	232	**4**	18	0	>6 000	11%	6%
Dump up Beach	at southern groin entrance to beach	MB 13	0 3	5	15	0	1 700	**7**	17	0	1 700	12%	12%
	center of beach	MB 14	1 2	**1**	16	0	17	**1**	18	0	17	0%	0%
North Gully	between N Gully and Dump up Beach	MB 16	0 3	5	9	1	290	**9**	11	1	670	18%	9%
	10 m seaward from mouth	MB 15	0 3	**5 724**	10	3 160	20 000	**6,051**	12	3 160	58 000	100%	100%
One man Beach	center of beach	MB 17	0 3	1	2			**1**	2				

Not available or not applicable

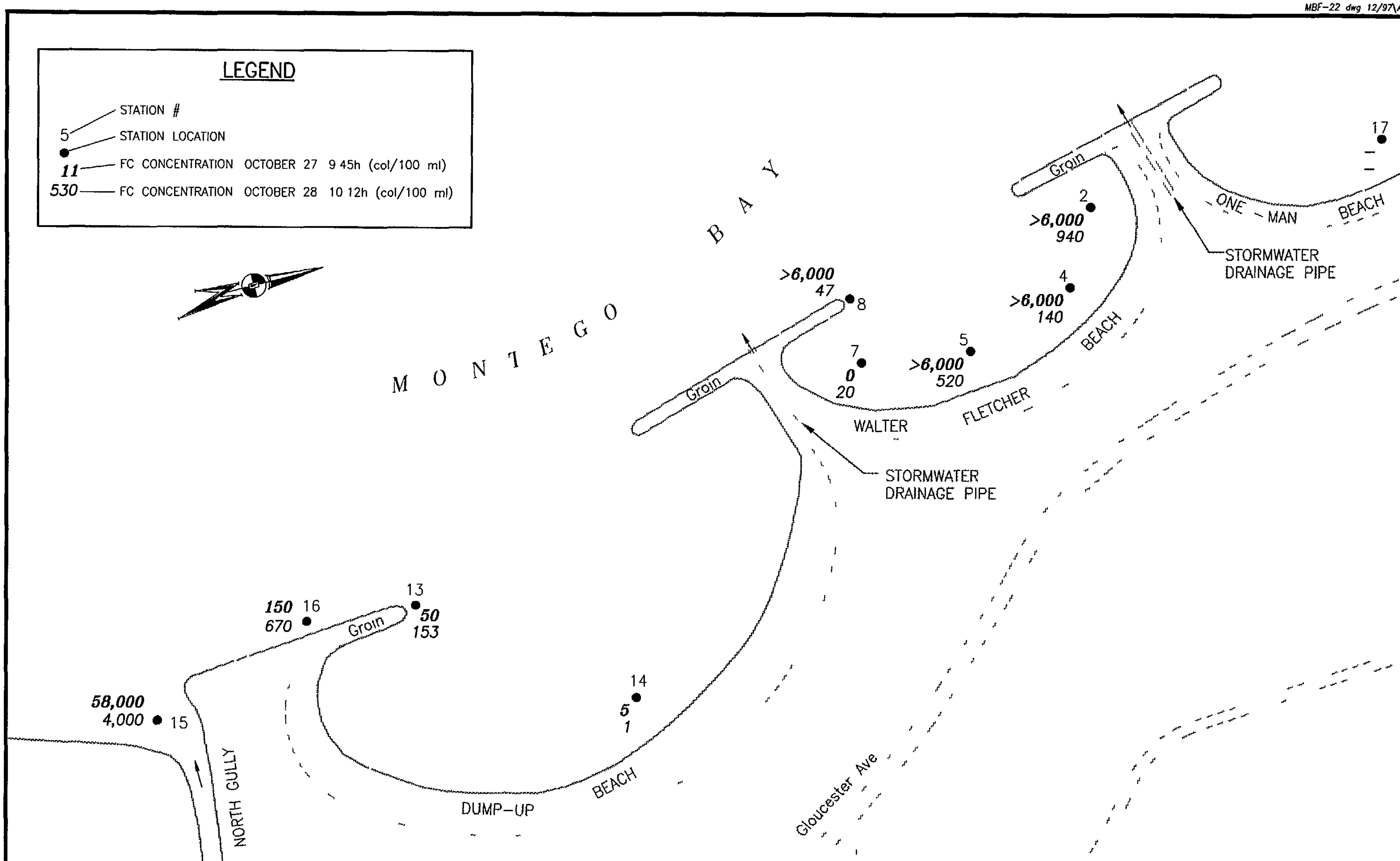


US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure 5-5
LOUIS BERGER INTERNATIONAL, INC	Scale 1cm = 40 meters	MONTEGO BAY - Faecal Coliform (Concentrations)
Technical Support Services, Inc.	December 1997	All Samples Sept 28 to Dec 12, 1997

MBF-21 dwg 12/97\AG



US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	**Figure 5-6**
LOUIS BERGER INTERNATIONAL, INC	Scale 1cm = 40 meters	**MONTEGO BAY - Fecal Coliform (% Exceedence)**
Technical Support Services, Inc	December 1997	**All Samples Sept 28 to Dec 12, 1997**



US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure 5-7
LOUIS BERGER INTERNATIONAL, INC Technical Support Services, Inc.	Scale 1cm = 40 meters	MONTEGO BAY - Fecal Coliform (Concentrations) High Values on Oct 27 and 28, 1997
	December 1997	

900 col/100 ml The generally lower concentrations on October 28 suggest that the concentrations were a result of dilution and die-off from loading during October 27 Concentrations on October 29 had returned to typical low dry weather concentrations The potential causes for these high concentrations are discussed below in Section 5 3 The high concentrations measured during these two days are the reason why, on average, the faecal coliform concentrations at some of stations along Walter Fletcher Beach exceeded the standard of 200 col/100 ml in a total of 11% of all samples analyzed during the study (Figure 5-8)

Dump-up Beach The faecal coliform concentrations at Dump-up Beach were always low, ranging between 0 and 17 col/100 ml This includes the faecal coliform concentrations on October 27 and 28, indicating the source affecting the Walter Fletcher Beach was unique to the beach

One-man Beach Two samples were collected during Sampling Event 4 during dry weather conditions The faecal coliform concentrations in these two samples were below 2 col/100 ml reflecting safe bathing conditions

Beaches - Wet Weather Conditions

Walter Fletcher Beach - August 28 samples The beach was sampled approximately 18 hours after a larger rainstorm in Montego Bay Samples were analyzed by the NWC laboratory in Bogue The faecal coliform concentrations ranged between 2 and 60 col/100 ml along the beach which is clearly above typical dry weather conditions, but still below the USEPA standard for swimming The beach was closed for swimming after the storm, reportedly because of debris on the beach Some residual solid waste in the northern corner of the beach indicates that the beach was indeed affected by stormwater runoff

Walter Fletcher Beach - October 3 samples An 'average' rainstorm occurred in Montego Bay on the evening of October 2 Samples were collected between 9 30h and 10 30h on the following day, 14 hours after the storm Clearly, faecal coliform concentrations at Walter Fletcher Beach had increased from dry weather concentrations between 0 to 5 col/100 ml to concentrations between 2 and 28 col/100 ml However, these higher concentrations were still within the USEPA standard The only sample exceeding the USEPA standard on October 3 was measured as 232 col/100 ml at the entrance to the crescent-shaped beach area at Station MB-8 This station is located outside of the swimming zone The higher concentrations may have been caused by residual faecal coliform bacteria from the storm 14 hours earlier Concentrations were also high at the entrance to Dump-up Beach (Station MB-13, 707 col/100 ml) suggesting that North Gully could have been a source

Dump-up Beach Samples were not collected on Dump-up Beach on August 28 The faecal coliform concentration in the sample collected from the beach on October 3 was very low (5 col/100 ml)

One-man Beach Samples from the beach collected after rainstorms are not available

5 3 Discussion

'Typical' dry weather conditions The data show that the three beaches, Walter Fletcher Beach, Dump-up Beach, and One-man Beach are typically safe for swimming during dry weather conditions However, due to the surprisingly high concentrations that were measured on October 27 and 28, the Walter Fletcher Beach could exceed the USEPA standard some of the time during dry weather conditions

Walter Fletcher Beach - High faecal coliform concentrations on October 27 and 28 The cause for the high concentrations is not understood at this time The data are not likely an analytical error since (a) high values occurred on both days, (b) high results were recorded by two laboratories independently, and (c) high concentrations were measured along most of the stations along the beach during these days Rainfall in Montego Bay was not a factor, as shown by the rain gage records both from the airport and the NWC location Possible sources include the following (although they cannot be confirmed at this time)

- *Stormwater drainage pipes* Dry weather discharges could have occurred at one of the two stormwater drainage pipes at either side of the Walter Fletcher Beach Such dry weather discharges could potentially consist of sewage entering the system through a broken sewage pipe or through pumping within the upland drainage area of the pipe, although the area that is drained by the each of the pipes is not known at this time

- *North Gully* The faecal coliform concentration at the mouth of the gully was comparatively high (58 000 col/100 ml) However, North Gully was probably not the source unless rainfall occurred in the upper watershed of the gully Unusual discharge in the gully were not reported by local residents Also, the concentrations at the stations between the gully and Walter Fletcher Beach (Stations MB-13,16) were comparatively low suggesting that coliform-laden gully water was not transported along the coast In addition, had North Gully been the source, it is conceivable that Dump-up Beach would have been affected as well Concentrations at Dump-up Beach on October 27 and 28 were below 20 col/100 ml, as tested by both the NWC and our laboratory on both days

- *Discharges along the beach* The only larger source for faecal coliform along the beach is the sanitary facility for the beach itself It is not conclusively known yet if the facilities is connected to the wastewater collection system of the City or if the facilities has another form of sewage treatment This issue should be resolved The sharply higher faecal coliform concentrations along the beach on October 27 and 28 suggest, however, that the source is not slow leaching from a leaking underground septic system but rather a more direct discharge involving dumping or pumping

- *Boat discharges* Several boats are moored in the northern corner of the beach Nobody lives on these boats In addition, these boats do not have sanitary facilities, thus, dumping of a sewage holding tank after return from the sea is not an option

Wet weather conditions The collected data are insufficient to fully understand the faecal coliform concentrations during wet weather conditions at the beach and the impacts of the potential sources Closure of the beach after the August 27 storm by the beach operator and residual solid waste in the northern corner of the beach suggests that the beach *is* affected by large storms Half a day after the storms occurred, faecal coliform concentrations were within the USEPA standard Open questions consist of the following

- *Size of Rainstorm* Do large rainstorms result in faecal coliform concentrations above 200 col/100 ml along the beaches (Walter Fletcher Beach, Dump-up Beach and One-man Beach)? If so, what size of rainstorm (in terms of rainfall rate) affects the beaches such that the faecal coliform concentrations exceed standards for safe bathing?

- *Length of Influence* If the water quality of the beaches is affected, how long does it take after a storm before dilution and die-off decreases the faecal coliform concentrations again to safe bathing levels?

- *Sources* What are the main sources of faecal coliform that affect the beaches during a storm? All beaches could be affected by the two stormwater drainage pipes and by North Gully North Gully discharges much greater volumes of wastewater into the Montego Bay than the stormwater drainage pipes However, the stormwater drainage pipes are potentially important sources because they discharge closer to the Walter Fletcher Beach and the One-man Beach, even though the discharge volume is much smaller than for North Gully

- *Water Circulation* What is the water circulation in front of the beaches? In what way does the transport direction of the stormwater runoff vary once it enters the ocean? Is beach contamination driven by the magnitude of rainfall *and* storm influences on water circulation?

5 4 Recommendations

5 4 1 Source Reduction

The data suggest that the beaches are safe for swimming most of the time However, the source that resulted in the high concentrations along Walter Fletcher Beach on October 27 and 28 should be identified before the beach can be considered safe for swimming during dry weather at all times This identification includes the determination of the type of sewage facility on the property of the beach and a better understanding of the stormwater drainage pipes For example, additional surveys could try to determine if illegal sewage connections exist to the stormwater drainage pipes through water quality monitoring of these pipes If so, such connections should be located through dye studies and eliminated

Source reduction of wastewater (and garbage) entering North Gully certainly is highly desirable as well, although realistically is not expected to be achievable in the short-term Given the large number of small point and non-point sources that enter the gully, a study should be done first to identify these sources and then rank them in terms of significance Such a study would need to address both dry weather and wet weather conditions

If North Gully is an important faecal coliform source to the adjacent beaches then a simple modification of the outlet to allow greater dilution or to enhance outward dispersion of the stormwater plume may be a cost-effective approach to remediate the problem

5 4 2 Beach Management

The most realistic option in the short and medium term for Walter Fletcher Beach is beach management, assuming the source for the high concentrations on October 27 and 28 has been eliminated Managing the beach is simple because the beach is surrounded by a fence and gate However, at this time, additional data are required to determine when and for how long the beach should be closed due to increased risk from coliform bacteria

Dry weather data The number of dry weather data available at this time is sufficient for a management plan However, additional data are required for the determination of the source that resulted in the high concentrations on October 27 and 28

Wet weather data Wet weather data are clearly insufficient at this time for the development of a management plan Data of several rainstorms during and at different times after the storm are needed The sampling approach should be designed to address the open questions listed in Section 5 2 above

Once sufficient data are available and the source for high values on October 27 and 28 has been eliminated, a management plan may contain the following elements

- *Walter Fletcher Beach* The beach is open for swimming during dry weather During wet weather, the beach could be closed after a specific rate of rainfall over a specific period of time The rain rate could be measured with a simple rain gage at the entrance to the Walter Fletcher Beach, with potentially a second gage at the Montego Bay Marine Park (MBMP) Office for purposes of enforcement The beach should also be closed if garbage and other floating matter is seen on the beach after rain, independent of the rain rate

- *Dump-up Beach and One-man Beach* These two beaches are not enclosed by a fence as Walter Fletcher Beach Therefore, *if* these beaches are unsafe for swimming shortly after rainstorms, effective management of these beaches is likely based on informing the public Managing the beaches could potentially consist of two options

  - Setting up a sign that states that beaches are safe for swimming, except after larger rainstorms

  - Giving the responsibility of beach management to the MBMP After severe rainstorms (using data from a simple rain gage deployed at the nearby MBMP headquarter), a sign could be put up by the Park at each beach stating that the two beaches are closed for swimming for the remainder of the day

However, we need to stress that the available wet weather data are not yet sufficient to recommend implementation of either one of these options In addition, source identification may allow single reduction options which reduce demands of beach management

5 5 Suggested Activities for Development of Beach Management Plan

As part of this project we recommend the following activities toward the goal of safe swimming conditions along the three beaches (Walter Fletcher Beach, Dump-up Beach, and One-man Beach)

- *Identification of the source that resulted in the high concentrations on October 27 and 28* This survey would consist of a information search as well as additional sampling near the stormwater pipes It may also require a dye study to trace potential sources

- *Collection of wet weather data* Samples during and at different intervals after a few storms are needed The survey would include tracking of the stormwater discharge and the direction of movement of the water entering from North Gully into Montego Bay Salinity measurements would be made in conjunction with the collection of faecal coliform samples, salinity is a tracer for the direction of flow of the coliform-laden stormwater In addition, visual observations would be recorded (such as color of water, garbage distribution, turbidity, etc) as other tracers of movement

- *Circulation data processing* Detailed data on the direction of water movement in front of Walter Fletcher Beach were collected during the Montego Bay Environmental Monitoring Programme (1991 to 1996) Water velocity and direction measurements were recorded continuously every 15 minutes for 2 weeks during the rainy seasons and 2 weeks during the dry season This information would be reprocessed to provide information of the 'typical' flow direction of water entering the bay from North Gully This study will support the source identification and development of the beach management plan It should also provide insight into the potential for reconfiguring the gully outlet to enhance flow away from the beaches

- *Other indicators for pathogens* During our sampling events, tests were also conducted for enterococcos as another bacterial indicator These data are currently still being synthesized We plan on processing these data further and comparing them with the faecal coliform results as a second indicator for pathogens

- *Rainfall analyses* We plan to conduct statistical analyses of existing rainfall records collected over the last years at the Sangster International Airport and from the watershed of Montego River (if available) to determine the frequency and distribution of rainstorms in the area, and thereby predict the likely frequency of beach closure given specific rain rates

- *Source identification for North Gully* A separate study should be performed that identifies the main non-point and point sources for sewage entering the gully, as well as the sources for garbage The study should also address conditions during dry weather and wet weather conditions This study should be comprehensive to be useful and therefore may need to be conducted as a separate project

6.0 NEGRIL - Community Centre Beach

6.1 Overvıew

The Communıty Centre Beach ıs located ın Negrıl along the southern stretch of the well-known 7-mıle long beach along Long Bay (Fıgures 6-1 and 6-2) The beach ıs located adjacent to a Communıty Centre for the Town and has easy access to the publıc There are no hotels adjacent to the beach

The South Negrıl Rıver (Fıgures 6-3 and 6-4) enters the ocean just to the south of the beach The rıver draıns the Great Morass In addıtıon, ıt receıves stormwater runoff from adjacent communıtıes, namely the Towns of Negrıl and Sheffield At present, a new wastewater treatment system ıs constructed adjacent to an upstream sectıon of the rıver The effluent from the new treatment plant ıs expected to be dıscharged ınto the rıver later thıs year (Fıgure 6-5)

The South Negrıl Rıver water has a characterıstıc rusty brown color, the water affects the beach at tımes (Fıgures 6-6 to 6-9) The coloratıon ıs caused by humıc substances such as tannıc acıds whıch do not affect human health Therefore, the color does not ındıcate contamınatıon However, the brown color serves as a useful tracer for the transport dırectıon of other constıtuents ın the rıver water (such as colıform) after entry ınto the ocean

6 2 Data

6 2 1 Raınfall

Most of the samples were collected durıng dry weather condıtıons Raınfall only occurred ın the afternoon of October 1 and 2 (Table 6-1) The raınfall rate of the storm on October 1 was low (2 mm), the rate on October 2 was 10 mm Samplıng was conducted around noon on each followıng day

Raın fell also ın the afternoon of November 1 The raın started at 15 45h and ended at 17 00h The raın rate ıs estımated roughly wıth 5 to 10 mm ın Negrıl, although a raın gage was not deployed at the tıme The raınfall was local only, no raınfall was recorded at the South Negrıl Lıghthouse The tıde at the tıme of raınfall was ıncomıng, therefore none of the stormwater runoff that draıned ınto the South Negrıl Rıver dıscharged ınto the ocean untıl the tıme of the outgoıng tıde approxımately 4 hours later

6 2 2 Flow Rates of South Negrıl Rıver

The South Negrıl Rıver ıs an estuary, that extends all the way to Sheffield The salınıty of the surface water ın the rıver (upper 30 cm) varıes from roughly 25 parts per thousand (ppt) near the mouth of the rıver (Statıon NG-11) to 3 ppt east of the footbrıdge (Statıon NG-22, Fıgure 1-4) The salınıty of the surface water varıes dependıng on the ınflow of freshwater from the watershed of the rıver The salınıty of the bottom water ın the rıver (upper 20 cm) decreases only from 34 ppt near

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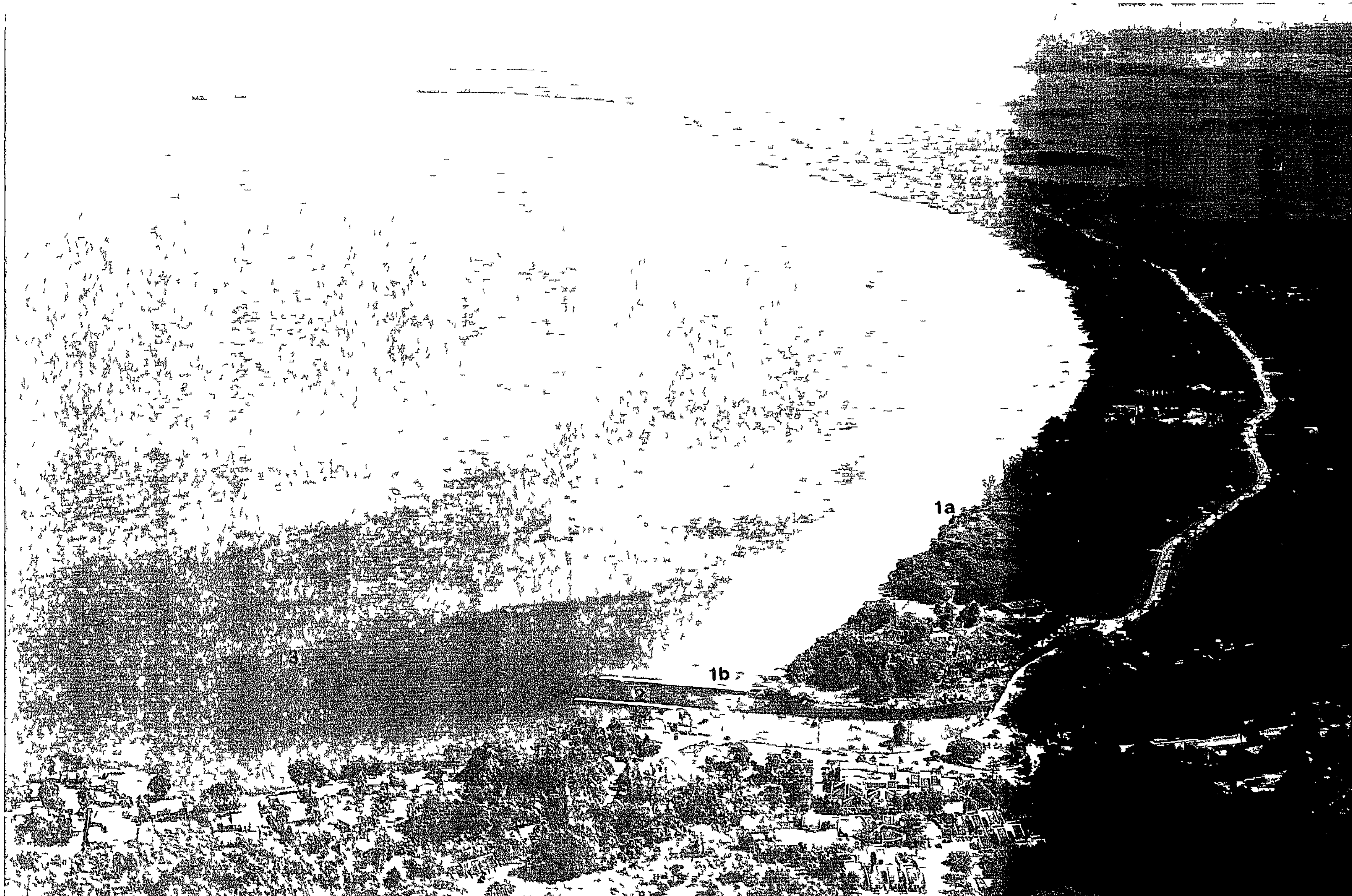

Figure 6.1 Long Bay in Negril looking north. The Community Center Beach (between 1a and 1b) extends north for approximately 400 m from the mouth of the South Negril River (1b). Upon entry into the ocean the plume of brown river water (3) is moving to the west. At times, depending on tides, wind and circulation patterns in the bay, the plume can move northward parallel to the beaches. The Great Morass is located to the east ... (Photo by ... S. Tyndale-Biscoe on 14 August 1985)

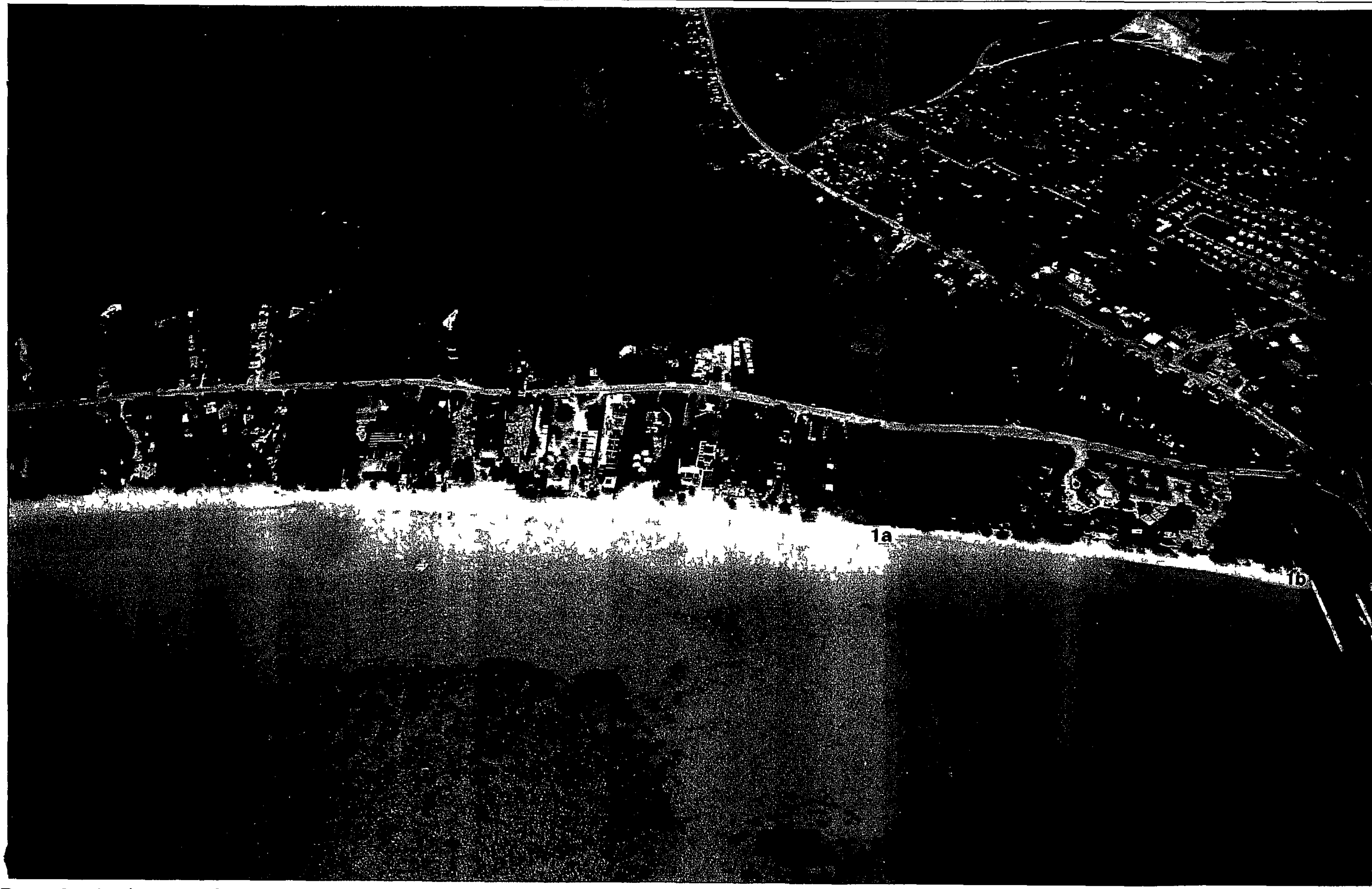

Figure 6-2 Southern part of Long Bay in Negril, looking east The Community Center Beach (between 1a and 1b) is just to the left of the mouth of the South Negril River (2) At this time, the brown water of the South Negril River (3) is also spreading northward affecting the water quality on the beach During our study, brown-water conditions" along the beach were observed on December 8 and 9 along the entire length of the beach in the photograph Point sources for fecal coliform entering the river include the effluent from the existing sewage treatment plant in White Hall (4) *(Photograph taken by J S Tyndale-Biscoe on 31 May 1994)*

Figure 6-3 South Negril River upstream near the Town of Sheffield (near sampling station NG-21) The river is comparatively narrow The salinity of the bottom water is 32 parts per thousand which is close to ocean water Non-point source runoff from Sheffield appears to be one of the sources for faecal coliform in the river

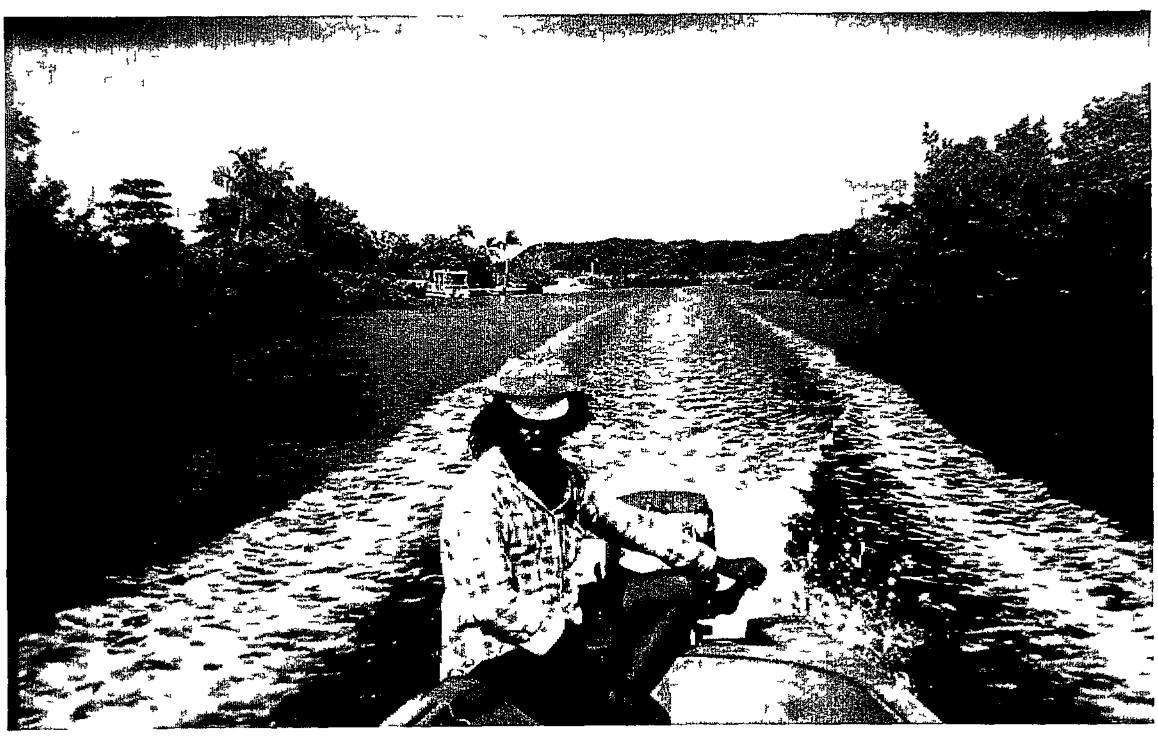

Figure 6-4 South Negril River, downstream near the Town of Negril (near sampling station NG-18) The river is comparatively wide The main sources for faecal coliform in the river are likely small point and non-point sources from the Town of Negril Water samples were collected from a boat, operated by Mr Wayne Hall

75

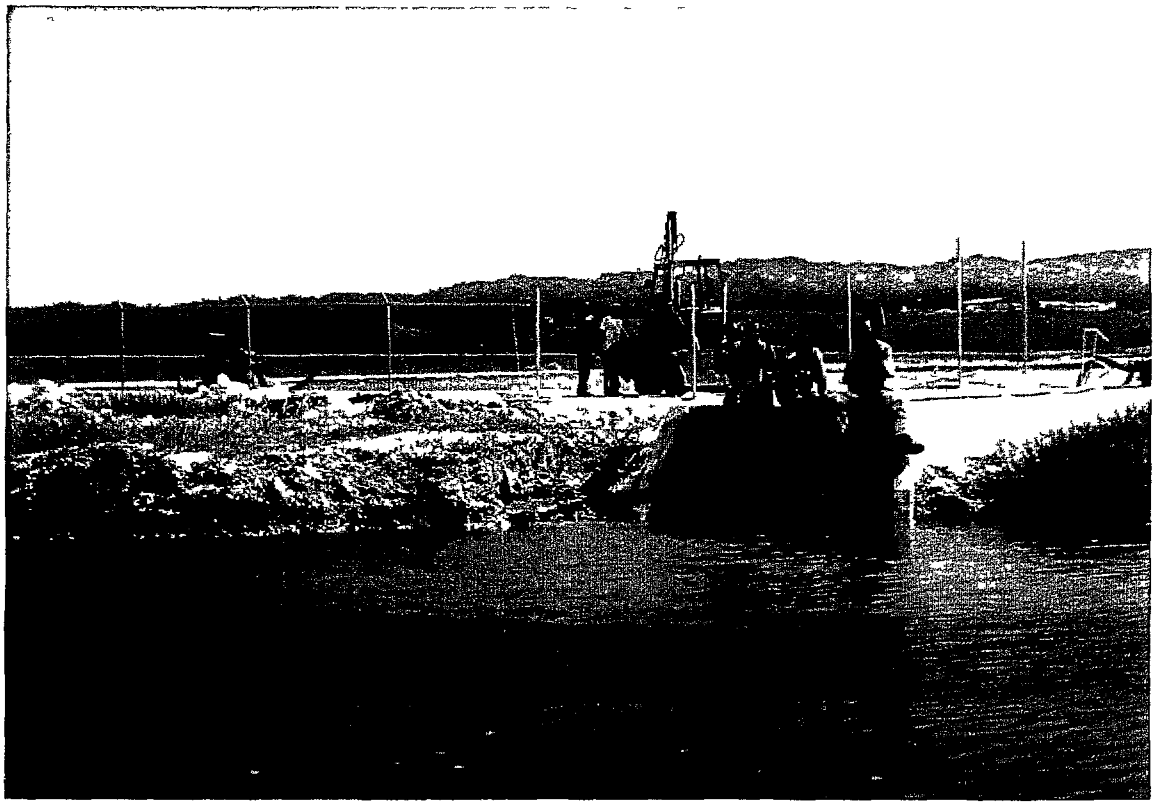

Figure 6-5 Later this year the new sewage treatment plant is expected to discharge effluent into the river The treatment plant consists of several waste stabilization ponds The effluent point is shown here, although the ponds are not operational yet Pre-discharge baseline conditions collected in this study should prove valuable for future studies of the effect of the sewage effluent on the water quality in the river and along the beaches, once sewage effluent is being discharged into the river

Figure 6-6 Community Centre Beach during "blue-water conditions" During such conditions, faecal coliform concentrations in the water are low or absent, the water is safe for swimming

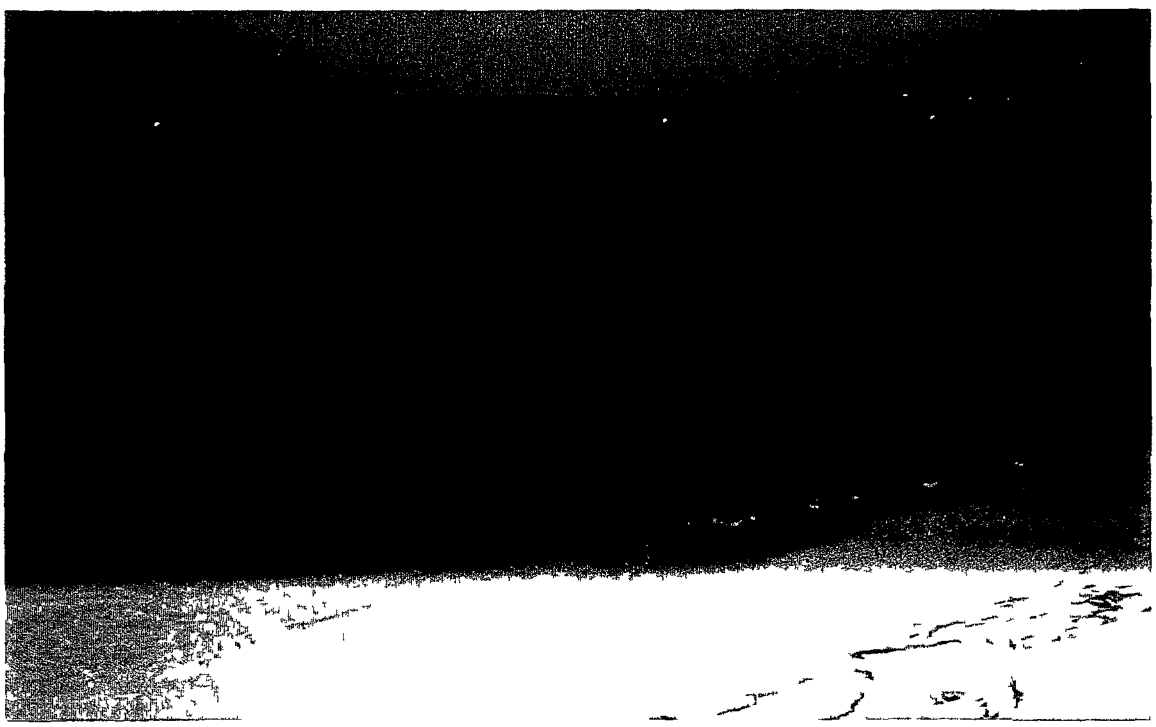

Figure 6-7 Community Centre Beach during brown-water conditions", as observed on December 8 and 9 The brown water is river water that moves to the north upon entry into the ocean The brown color is caused by compounds such as natural organic acids from the morass which don't affect human health However, (colorless) faecal coliform bacteria also contained in the river water may exceed concentrations for safe swimming under such conditions

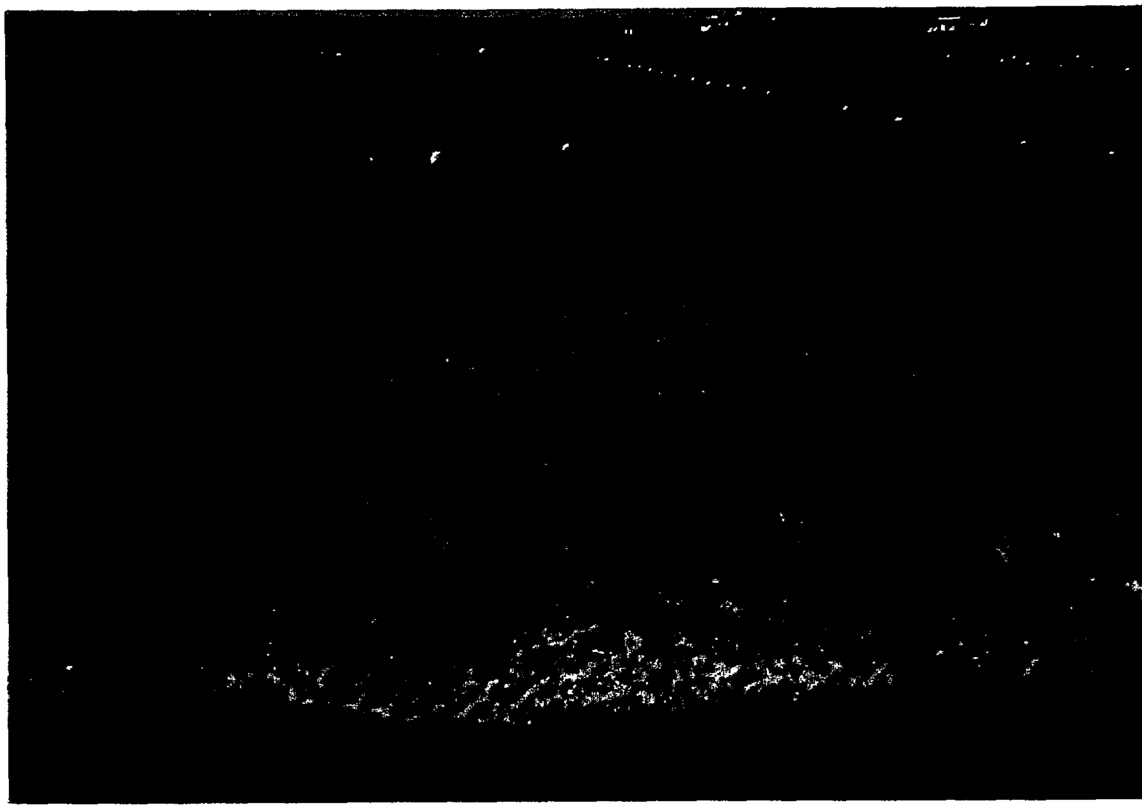

Figure 6-8 Closeup-up of "blue-water conditions" near the Community Centre Beach

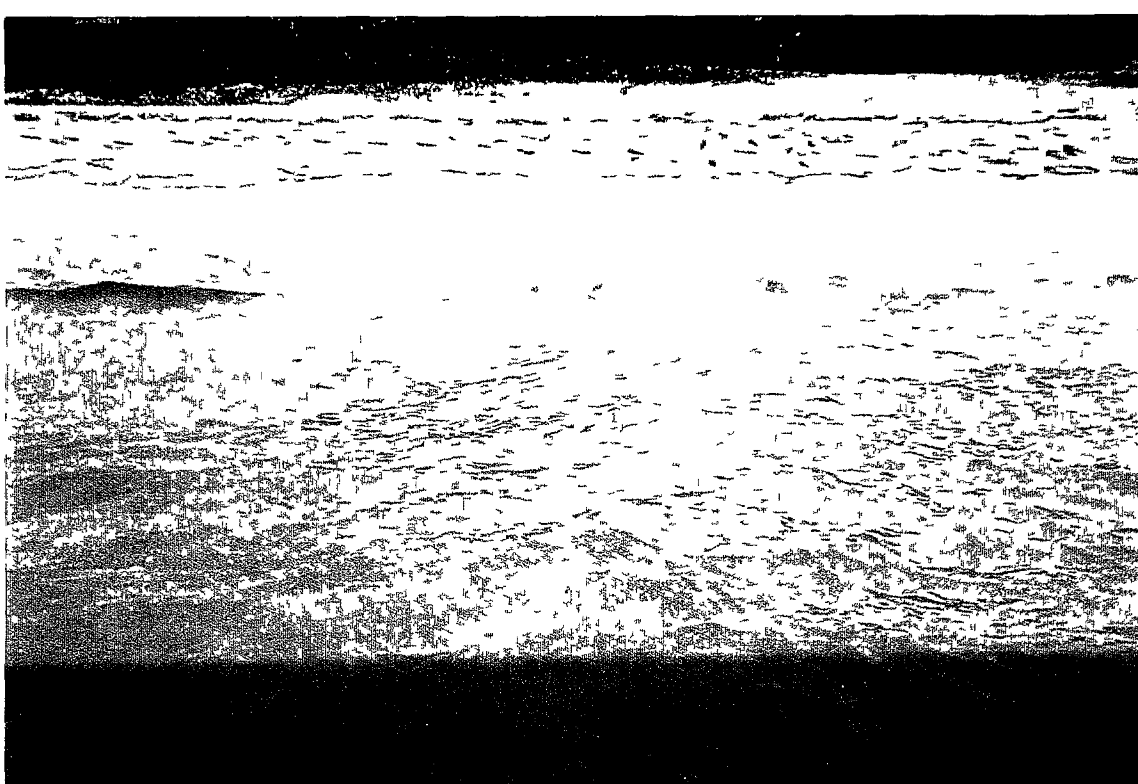

Figure 6-9 Closeup-up of "brown-water conditions" along the Community Centre Beach

Table 6-1

Rainfall near Negril, 1997 (in mm)

(Location Lighthouse at Negril Point)

Day	*Jan*	*Feb*	*March*	*April*	*May*	*June*	*July*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*
1									33 0	1 8		
2				7 3			5 0		39 2	10 0		4 0
3												
4		12 2			14 9	122 0						
5		9 6		58 8		23 0			16 1	3 6		10 7
6		3 4				2 2		6 5		23 7		
7			5 9		47 0							
8		9 1	1 1	0 9	2 6	2 2				5 3		
9			7 9				11 0			29 0		
10					5 6		17 0					
11						5 7						
12		32 9						7 0			16 9	
13								6 0	7 5		1 0	
14		1 7						2 0		66 0		25 3
15					8 3				2 5			
16					14 6							
17							16 0	7 0				
18		8 4										
19											15 0	
20		39 1			7 4	9 0	3 0	6 5			19 0	
21							26 0					
22							17 0	31 5	10 3			
23	27 5							39 0	8 4			
24	1 3	17 4				5 5	15 1	42 3	2 4			
25								2 5				
26							10 0				7 2	
27							5 0					
28					25 0		14 6					
29	28 9				87 0		2 3	7 0				
30							7 2			5 2	15 1	
31												
Sum	57 7	133 8	14 9	67 0	212 4	169 6	149 2	157 3	119 4	144 6	74 2	40 0
No of days	3	9	3	3	9	7	13	11	8	8	6	3

Statistics for the year no data

Total Rainfall	1 340 mm
Number of rain days	83 (without TR)
Highest rainfall volume in a day	122 mm

(Values represent rainfall between 7 00 am of the recorded day and 7 00 am of the next day)

Source Meteorological Office Kingston and Mr Johnson Negril

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the mouth of the river (Station NG-11) to 32 ppt east of the footbridge (Station NG-22) The salinity of ocean water in Long Bay is 35 ppt All salinity measurements varied to some extent depending largely on rainfall patterns, but essentially showed that the water in the river consists largely of near-ocean water with a comparatively thin surface layer consisting of a mixture between ocean and freshwater The thickness of the surface layer appears to be less than 0 5 meters (although was not studied in detail)

The flow of water in the South Negril River is tidal During incoming tide, river water does not enter the ocean except possibly during very large rainstorms with a large amount of stormwater runoff During the outgoing tide, the river slowly discharges into the ocean Rates of discharges during outgoing tide were not located, the rates vary depending on tidal conditions, hydraulic gradient in the watershed, and other factors Upon entry of the river water into the ocean, the water forms a brown trail parallel to the coast The trail is referred to in the text as a 'plume' The brown plume moves either toward the west, parallel to the cliffs (Figure 6-1), or toward the north, parallel to the beach (Figure 6-2) The plume was observed to be up to one kilometer long and less than 200 meter wide

The direction of the plume (northward vs westward) appears to be determined by tidal conditions as well as by wind conditions and the prevailing circulation pattern in Long Bay Information about the variability of these factors and their relative effect on the direction of the river plume has not yet been located or investigated

6 2 3 Faecal Coliform

During Sampling Event 1, samples were only collected from the Community Centre Beach, as requested in the Terms of Reference However, it became apparent during the study that in order to understand the mechanisms that determine the concentrations along the beach it was essential to also obtain data from the South Negril River and the ocean water along the cliff, west of the mouth of the South Negril River In addition, during days when the brown river plume was observed along the beach, samples were collected throughout the entire length of the plume, well beyond the limits of the Community Centre Beach

Data and statistical averages for each sampling event are presented in Attachment C, a summary of the data is presented in Table 6-2 and Figures 6-10 to 6-12

Dry Weather Conditions

South Negril River The highest faecal coliform concentration in the South Negril River were measured close to the mouth of the river (Station NG-11) Concentrations ranged from 120 to 12,300 col/100 ml with a geometric mean of 970 col/100 ml High faecal coliform concentrations were also measured occasionally up to 1 5 km further upstream (Station NG-12) In the mid-section of the river (Stations NG-17 to 20), faecal coliform concentrations were generally lower Faecal coliform concentrations increased again toward the Town of Sheffield (Stations NG-14,21,22) Concentrations at the mouth of the river (Station NG-10) were lower than 250 m upstream (Station

Table 6-2

Faecal Coliform Concentrations in Negril *(Statistics)*

Community Center Beach

SAMPLING EVENTS 2 to 4 September 28 to December 12 1997

Location		Station No	Water Depth *(appr m)*	FAECAL COLIFORM (col/100ml) *(Berger & NWC samples from Oct 3 and Nov 2)* Weighted Geometric Mean	Count	Mini mum	Maxi-mum	Percent of samples above 200 col/100 ml	Percent of samples above 400 col/100ml
				All Weather					
North of Community Center Beach	1 500 m from mouth of S N River (to Negril Gardens Hotel) 5m from shore	NG 37	0 8	**5**	2				
	1 250 m from mouth of S Negril River (to Sandi San Hotel) 5m from shore	NG 36	1 6	**2**	2				
	1 000 m from mouth of S N River (at Bar B Barn Hotel) 5m from shore	NG 34	0 8	**11**	3	6	26	0%	0%
	750 m from mouth of S N River (at Travellers Hotel) 30m from shore	NG 28		**2**	4	0	43	0%	-
	750 m from mouth of S N River (at Travellers Hotel) 5m from shore	NG 33	0 8	**37**	2				
	600 m from mouth of S N River (at Coral Seas Hotel) 30m from shore	NG 27		**16**	1				
	600 m from mouth of S N River (at Coral Seas Hotel) 5m from shore	NG 32	0 8	**17**	1				
	450 m from mouth of S Negril River 30m from shore	NG 1	1 6	**6**	12	0	3 130	8%	8%
	450 m from mouth of S Negril River 5m from shore	NG 31	0 8	**10**	1				
Community Center Beach	340 m from mouth of S Negril River 30m from shore	NG 3	1 6	**5**	12	0	230	8%	0%
	350m from mouth of S Negril River 5m from shore	NG 30	0 8	**13**	1				
	230 m from mouth of S Negril River 30m from shore	NG 5	1 7	**6**	12	0	330	8%	0%
	240 m from mouth of S Negril River 5m from shore	NG 25	0 8	**43**	3	10	60	0%	
	130 m from mouth of S Negril River 30m from shore	NG 7	2 0	**7**	12	0	350	8%	0%
	140 m from mouth of S Negril River 5m from shore	NG 29	0 8	**15**	1				
South Negril River plume	50 m northwest of northern jetty of river	NG 8	>6	**11**	12	0	510	17%	8%
	50 m west of river mouth	NG 9	>6	**224**	12	13	1 100	67%	25%
	250 m west of river mouth	NG 26		**18**	7	0	280	14%	0%
	450 m west of river mouth	NG 15		**13**	12	0	450	25%	8%
	800 m west of river mouth	NG 23		**1**	8	0	5	0%	0%
	1 300 m west of river mouth	NG 24		**1**	8	0	5	0%	0%
South Negril River upstream	mouth of river	NG 10		**366**	12	5	1 775	75%	75%
	250 m from mouth at N B Blvd bridge	NG 11		**965**	12	119	12 273	92%	83%
	900 m upstream from mouth	NG 18		**107**	8	5	580	25%	13%
	1 500 m upstream from mouth	NG 12		**304**	12	1	18 090	50%	50%
	1 800 m upstream from mouth	NG 17		**145**	8	10	1 420	38%	25%
	2 300 m upstream from mouth	NG 19		**189**	7	60	670	57%	14%
	2 800 m upstream from mouth	NG 13		**90**	8	12	500	38%	13%
	3 200 m upstream from mouth	NG 20		**116**	7	30	470	29%	14%
	3 800 m from mouth at NWC ponds	NG 14		**552**	9	210	8 800	100%	44%
	4 400 m upstream from mouth	NG 21		**234**	6	125	530	33%	33%
	4 700 m upstream from mouth	NG 22		**359**	3	250	530	100%	33%

Not available or not applicable

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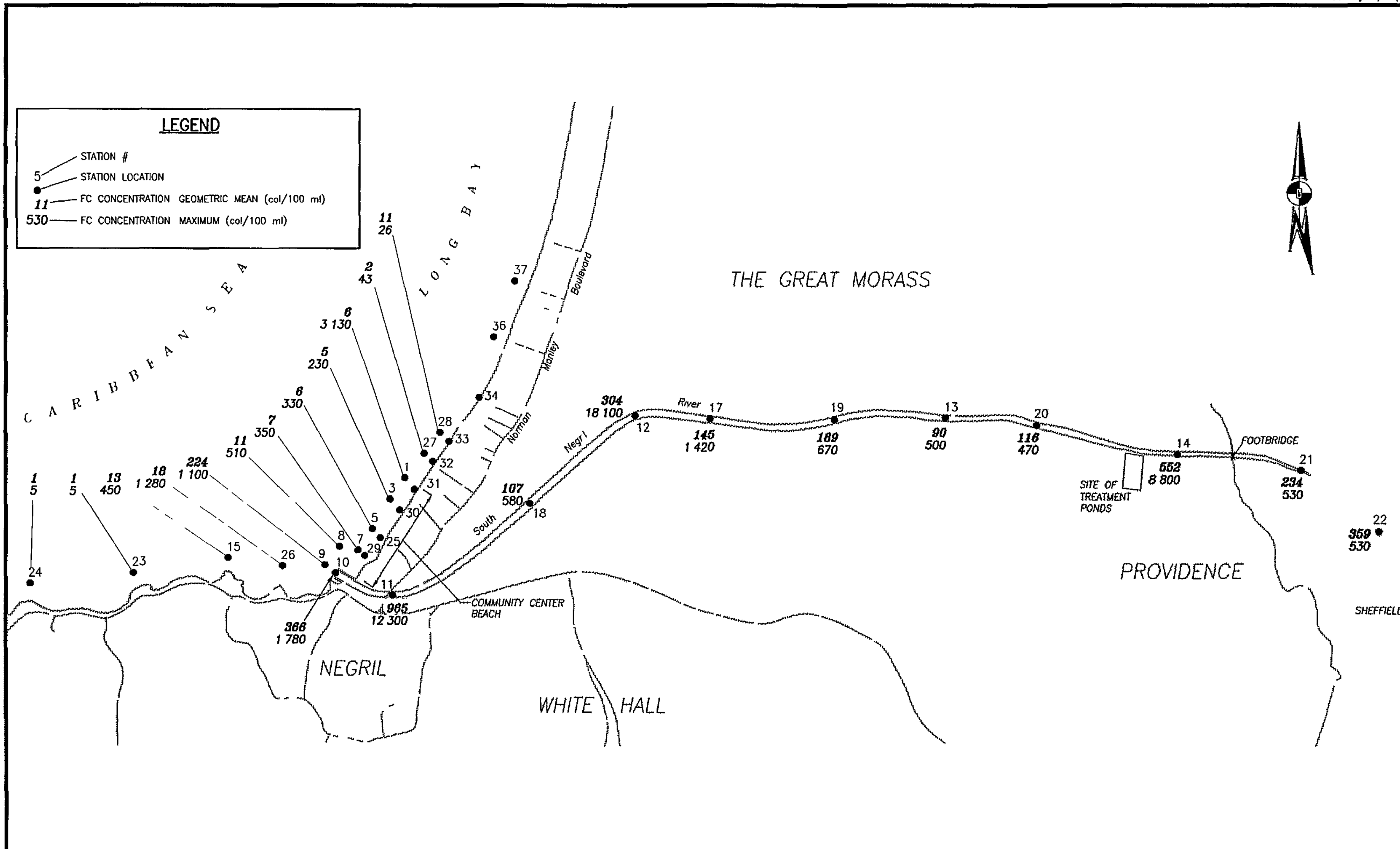
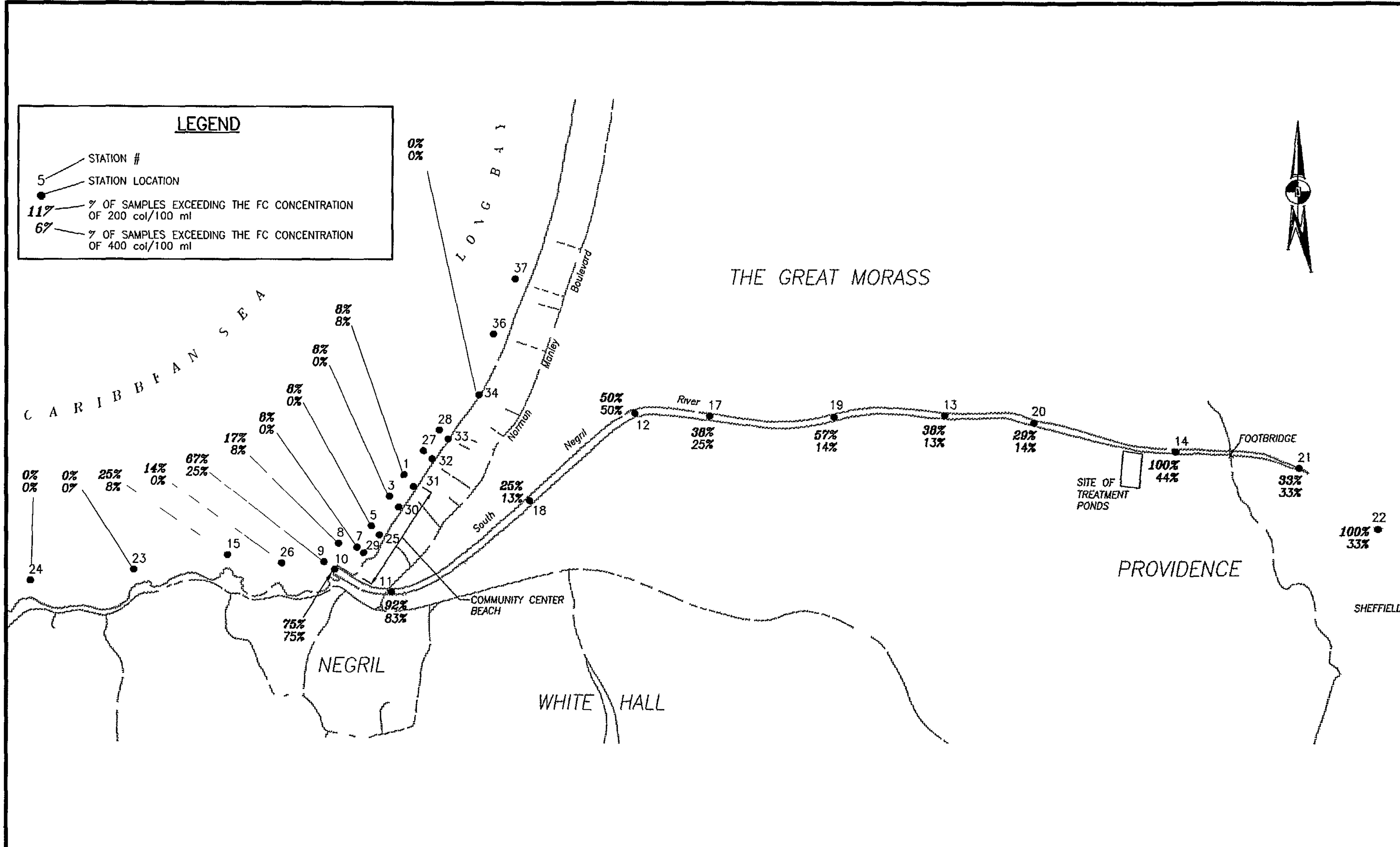


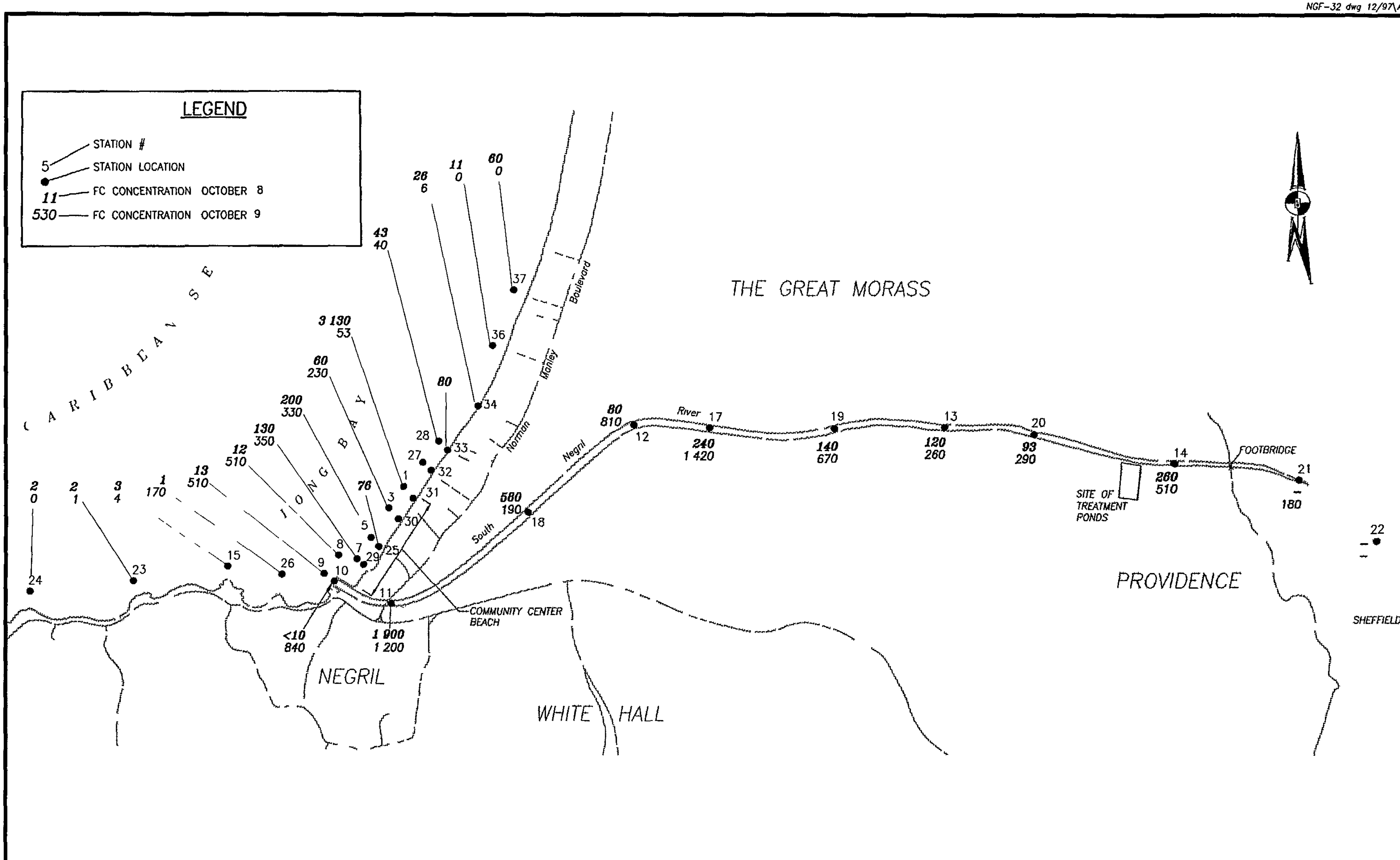
US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure 6-10
LOUIS BERGER INTERNATIONAL, INC Technical Support Services, Inc	Scale 1cm = 200 meters	NEGRIL - Faecal Coliform (Concentrations)
	December 1997	All Samples Sept 28 to Dec 12, 1997

NGF-31 dwg 12/97\A.G



US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure 6-11
LOUIS BERGER INTERNATIONAL, INC	Scale 1cm = 200 meters	NEGRIL - Faecal Coliform (% Exceedence)
Technical Support Services, Inc	December 1997	All Samples Sept 28 to Dec 12, 1997

NGF-32 dwg 12/97\A.G



US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	**Figure 6-12**
LOUIS BERGER INTERNATIONAL, INC Technical Support Services, Inc	Scale 1cm = 200 meters	**NEGRIL - Faecal Coliform (Concentrations)**
	December 1997	**Brown Water Along Beach (Dec 8 to Dec 9, 1997)**

NG-11), due to dilution of the river water with ocean water at the mouth, specifically during incoming tides

Community Centre Beach The faecal coliform concentrations along the beach ranged mostly from 0 to 350 col/100 ml, one single sample on December 9 was measured with 3,130 col/100 ml (Table 6-2, Figure 6-10) Most of the time, the faecal coliform concentrations along the beach did not exceed the USEPA standard of 200 col/100 ml (Figure 6-11) There was a distinct difference between the times when the river plume was moving along the beach ("brown-water conditions") and when it was not ("blue-water conditions") (Figures 6-6 to 6-9)

- *Blue-water conditions'* During such conditions, the water along the beach was turquoise blue like the ocean water and the salinity along the beach reflected 'pure' ocean water (35 ppt) The faecal coliform concentrations along the beach were generally close to 0 col/100 ml The water was safe for swimming

- *Brown-water conditions* The brown color in the water from the river varied depending on the amount of river water mixed with ocean water On days with traces of brown river water ("light-brown conditions"), the faecal coliform concentrations increased to double-digit values, yet did not exceed the USEPA standard (e g , on October 30, Attachment C) The highest faecal coliform concentrations were measured on December 8 and 9, on both days the color of the water was distinctly brown (Figure 6-9) Concentrations exceeded the USEPA standard on October 8 at Station NG-1 with 3,130 col/100 ml and on December 9 at Stations NG-5 and NG-7 (Figure 6-12) The faecal coliform concentration at any station north of the Community Centre Beach never exceeded the standard Due to the high concentrations measured on October 8 and 9, the faecal coliform concentrations in all samples were 8% of the time over the USEPA standard (Figure 6-11) However, please note that brown waters were only encountered on two of the 13 sampling days

Wet Weather Conditions

South Negril River - October 3 Faecal coliform concentrations in the river were considerably higher than during dry weather conditions

South Negril River - November 2 Faecal coliform concentrations in the river 18 hours after the rainstorm were not significantly different than faecal coliform concentrations during dry weather conditions This may be be a result of the fact that the rainfall occurred only locally, not in the entire watershed of the river

Community Centre Beach - October 3 Faecal coliform concentrations along the beach were between 20 and 70 col/100 ml The plume of the river water moving westward at the time of sampling These data indicate that the direction of the river plume may be more important for the water quality along the beach than rainfall This indication need to be investigated further, however

Community Centre Beach- November 2 Faecal coliform was not detected along the beach when it was sampled 18 hours after the rainstorm

6 2 4   Salinity

Aside from the color of the water, salinity appears to be a useful tracer for water quality along the beach (Figure 6-13) The salinity in the water is a function of the degree of dilution of the river water in the ocean Generally, the higher the salinity along the beach, the more the coliform-laden river water is diluted by 'coliform-free' ocean water While subtle differences in ocean color are difficult to quantify, lower salinity values along the beach correlate with higher faecal coliform concentrations Since only two days with brown water were monitored, the data are still limited With additional data, it appears that salinity could be developed into a simple-to-use management tool for the Community Centre Beach

6 3 Discussion

Clearly, the water quality along the Community Centre Beach is determined by the direction of the plume of the South Negril River upon entry in the ocean When the plume is absent or moves to the west, the water along the Community Centre Beach is turquoise blue and the faecal coliform concentrations are very low, i e , the water is safe for swimming When the plume moves to the north, parallel to the beach and the water along the beach is brown, the water may exceed the USEPA standard of 200 col/100 ml Generally, it appears that the faecal coliform concentrations do not exceed the USEPA standard when the waters are only light brown When the water along the beach is deeper reddish-brown, the river water is less diluted and faecal coliform concentrations are higher, at times exceeding the USEPA standard Please note, however, that data during "brown water conditions" are still limited, data for "blue water conditions" are sufficient

The faecal coliform that is transported to the ocean by the river appears to enter the river from sources in the downstream section, i e , the community of Negril abutting the river Potential point sources are pipes along the river from the existing sewage treatment plant in White Hall, smaller hotels along the Norman Manley Boulevard, and possibly other developments These pipes are not visible from the surface, however

A second source appears to be runoff and non-point source discharges from the Town of Sheffield, as indicated by higher faecal coliform concentrations in the upper section of the river than in the mid-section

Other non-point sources during rainstorms may be runoff from animal farms adjacent to river

6 4 Recommendations

6 4 1   Source Reduction

The main point and non-point sources entering the river should be identified This survey should be conducted both in the vicinity of the Town of Negril and the Town of Sheffield Point sources should be mitigated to the extent possible Rerouting of direct surface discharges to infiltration basins or pits may be a cost-effective option to reduce contamination Some of the point sources may be removed once the new sewage treatment plant comes on line Such point sources could be

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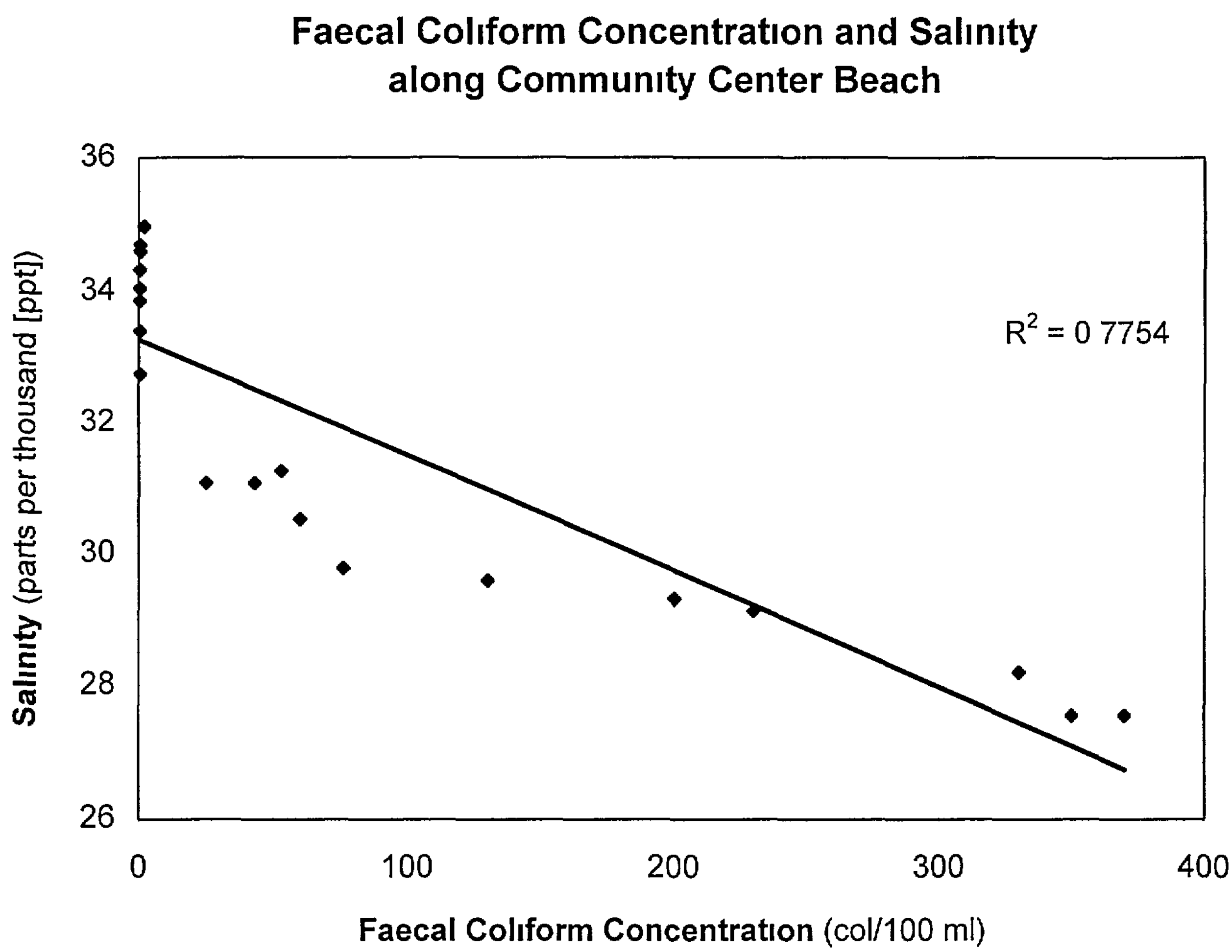
Figure 6-13



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hotels and other establishments that discharge sewage into the downstream section of the river, these establishment should be connected to the new system in the future Given that the river is draining largely rural areas and that the river faecal coliform concentrations are typically below 1,000 col/100 ml, reducing the sources for faecal coliform as a means to improve the faecal coliform concentrations along the beach should be viewed as feasible option over the medium term

6 4 2 Beach Management

In the short term, the beach should be managed Management options should be simple and easy to implement The limited data up to the present show that the water during 'brown-water conditions' could exceed the USEPA standard for swimming At the same time, the faecal coliform concentrations along the beach appear to relate to salinity We recommend to obtain additional detailed data that focus on the river plume at different tidal stages and the corresponding salinity If indeed a strong relationship between faecal coliform and salinity can be established, salinity along with color could become a simple management tool for local organizations Salinity can be measured directly within 10 seconds, faecal coliform measurement require a laboratory and would not be available for 24 hours

Encouraging is also that faecal coliform concentrations during 'brown water conditions' only exceeded the USEPA standard along a stretch of 400 m from the mouth of the river, even though brown water was found along the beach for more than twice that distance This condition should be confirmed through faecal coliform analyses of additional 'brown-water conditions' The conditions along the Community Centre Beach are ideal for the implementation of a 'low-intensity' management plan

The effect of rain on faecal coliform concentrations in the river has not yet been established Rain water is likely increasing the faecal coliform concentration Higher faecal coliform concentrations at the river mouth result in higher concentrations in the plume (even after dilution with ocean water) compared to dry weather conditions However, given the fact that the river is tidal and thus the stormwater does not necessarily drain immediately into the ocean, the effect of the stormwater runoff on the faecal coliform concentration in the ocean may be reduced Samples collected just before and after a few rainstorms should answer the question of the role of rain on the water quality along the beach

6 4 3 New Treatment Plant

The effluent and the performance of the new sewage treatment plant should be carefully monitored (once the plant is operational) to assure that it does not become a new source If the faecal coliform concentration in the effluent is 200 col/100 ml as planned, there should be no impact on the water quality of the beaches

6 5 Suggested Activities for Development of Beach Management Plan

As part of this project we recommend the following activities toward the goal of safe swimming conditions along the Community Centre Beach (and beaches further to the north)

- *Identification of the main point and non-point sources that enter the South Negril River* This survey will consist of a information search and field survey It may also require a dye study to trace potential sources We will work closely with organizations and authorities in Negril for tracking these sources

- *Collection of wet weather data* Samples during and at different intervals after a rainstorm are needed The survey would include tracking of the stormwater discharge and the direction of movement of the river plume entering the ocean Salinity measurements would be made in conjunction with the collection of faecal coliform samples In addition, visual observations would be recorded (such as color of water, garbage distribution, turbidity, etc) as other tracers of movement Further, a tide gage would be deployed to record tidal conditions continuously

- *Collection of additional brown-water conditions data* Samples for faecal coliform analyses during additional 'brown-water conditions' would be collected from the beach area Salinity measurements would be made at the same time, both in the field and in the laboratory on the collected samples A correlation would be established for salinity and faecal coliform for beach management Data would be collected also from the entire length of the plume Dry weather data suggest that concentrations diminish rapidly with distance down the beach from the river Only a portion of the beach may need to be managed

- *South Negril River data base* A data base with existing data about the South Negril River would be established This data base would include the information about flow rate, tidal range, and water quality It would also include information about factors that influence the direction of the plume such as tides, wind and currents, etc In addition, in cooperation with the Negril Area Environmental Protection Trust (NEPT) and/or the Negril Coral Reef Preservation Society (NCRPS), a simple visual monitoring programme would be established to determine the frequency of 'brown-water conditions' along the beach This programme would consist of recording tidal elevation, water color, salinity, and wind conditions several times a day at the beach This data base would subsequently be reviewed to determine the frequency with which unsafe conditions may occur along the beach The complete data base would also be reviewed to determine if a more detailed oceanographic survey was advisable to better understand the variability in the movement of the plume

- *Other indicators for pathogens* During our study, analyses were also performed for enterococcos as another indicator These data are currently still being synthesized We plan on processing these data and comparing them with the faecal coliform results as a second indicator for pathogens

- *Rainfall analyses* We plan to conduct statistical analyses of existing rainfall records collected over the last years at the South Negril Lighthouse and from the watershed of South Negril River (if available) to determine the frequency and distribution of rainstorms in the area

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7.0 LONG-TERM MONITORING PLAN

Long-term monitoring is desirable for the management and the protection of public health at the four beaches Such monitoring should start once the range of conditions along each beach as investigated in this study is fully understood and a Beach Management Plan has been developed Monitoring should presumably be conducted by the NRCA, possibly in collaboration with local NGOs Monitoring should be done for the different types of common conditions along each beach For all beaches monitoring should be done during dry and wet weather conditions Samples should also be taken from the most significant coliform sources, such as the Turtle River, South Negril River, and the stormwater drainage pipe in Ocho Rios

The monitoring frequency should be tailored to the expected variability of coliform concentrations and patterns of beach use NRCA's current beach monitoring frequency of 3 months is considered adequate for dry weather monitoring Additional monitoring should be scheduled for selected rain events, however In addition, in Negril, sampling should be conducted during 'brown-water conditions' Rain and brown-water sampling events are not very predictable Therefore, they require that sampling equipment and staff are prepared to go sampling on short notice At the same time, the laboratory should have sufficient capacity to handle additional samples

Given that additional data are expected to be collected for this study, we would like to defer our recommendations for detailed site-specific monitoring plans at this time The additional data hopefully to be collected as part of thi study will include wet weather data, the information provided by such data should be considered to assure that long-term monitoring will provide the information desired

8.0 SUMMARY

All four beaches have water quality problems under certain conditions These conditions are distinctly different at each one of these beaches The only common problem at these four beaches is that rainfall generally causes the faecal coliform concentrations to increase The amount of increase depends of the proximity of the beach to stormwater runoff pathways (such as rivers, gullies, and drainage pipes)

The good news is that measures can be implemented to either reduce the sources of coliform to these beaches, and/or to manage these beaches to reduce the risk to human health during adverse conditions Given that the causes for the water quality problems vary between the beaches, reduction measures and management options are specific to each beach

For Turtle Beach, the main source reduction measure consists of rerouting the main stormwater drainage pipe that currently enters the bay For Sailor Hole Beach, source reduction measures consist of reducing the coliform loads to the Turtle River from abutting establishments and residences For the Walter Fletcher Beach, source reduction measures consist of identifying and eliminating the source for sporadic high faecal coliform concentrations, and investigating the significance of the stormwater drainage pipes during wet weather In the long-term, a reduction of coliform loading to North Gully is desirable For the Community Centre Beach, source reduction measures consist of identifying and removing the main point sources of coliform to the South Negril River

While source reduction will improve the water quality in the medium-term, they will not be sufficient to avoid occasional occurrence of high faecal coliform occurrences along the beach Therefore, each of the four beaches should have a management plan that clearly identifies conditions when the water along the beach is safe for swimming, and when precautions are to be taken Much of the baseline data so far gathered in this study will form a basis for these management plan Clearly, however, additional data need to be collected for specific conditions in order to be able to address appropriate measures to be taken in each of these plans The type of additional data is discussed in the text The management plan would also specify site-specific monitoring

With a management plan in place and with the implementation of specific source reduction measures, these beaches can remain a resource without adverse risks to human health

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ATTACHMENT A

Faecal Coliform Concentrations and Distribution by Sampling Event:

OCHO RIOS

(Sailor Hole Beach, Turtle Beach, and Surrounding Areas)

Table A-1

Faecal Coliform Concentrations in Ocho Rios Bay (col/100 ml)

Turtle Beach and Sailor Hole Beach

SAMPLING EVENT 1 (Reconnaissance) August 26 to 29 1997

Location		Station No	Water Depth (appr m)	Tuesday 26 Aug: Sampl Time (h)	Faecal Coliform Concentration (col/100 ml): NWC Lab	Faecal Coliform Concentration (col/100 ml): Kolbusch Lab (3)	Rain / Notes	Friday 29 Aug: Sampl Time (h)	Faecal Coliform Concentration (6) (col/100 ml): Kolbusch Lab (Run 1)	Kolbusch Lab (Run 2)	*Mean* (Runs 1 and 2)	Rain/ Notes dry/ wet *(5)*
Sailor Hole Beach	10 m from public beach	OR 9	1 2	12 50	**35**		Rain fell for 1 hr appr 1 hr earlier *(1 2)*					
	20 m from public beach	OR 1	1 2	10 14	**180**	*3 540*	2 weeks ago (appr)	6 30	320	215	**268**	
	40m from public beach	OR 10	n/a	10 39	**16**		2 weeks ago (appr)					
	25 m from fishermen s beach	OR 2	1 5	10 21	**230**	*183*	2 weeks ago (appr)	6 32	180	80	**130**	
	west of fisherman s beach	OR 3	3 0	10 31	**200**	*107*	2 weeks ago (appr)					
	western cruise ship pier	OR 4	>15	10 33	**58**	*1 270*	2 weeks ago (appr)					
	eastern cruise ship pier	OR 5	>15	10 35	**60**	*137*	2 weeks ago (appr)					
Turtle River	20 m upstream from its mouth	OR 8	0 3	11 37	**5 500**	*TNTC*	Rain started 37 min earlier *(1)*	6 58	>20 785	1 500	**>11 000**	
	(later sample at Station OR 8)	OR 8	0 3	12 50	**>400**		Rain fell for 1 hr appr 1 hr earlier *(1 2)*					
Sailor Hole River	30 m upstream from its mouth	OR 6	0 3	11 30	**>20 000**	*360*	Rain started 30 min earlier *(1)*	6 54	620	TNTC	**>620**	
Turtle Beach	center near boat pier	OR 7	n/a	11 18	**79**	*307*	2 weeks ago (appr)					
	west near Sand Castles	OR 9	3 0	10 48	**<2**	*87*	2 weeks ago (appr)	6 36	52	46	**49**	
	center near glassbottom boat area	OR 10	1 3	10 51	**<2**	*53*	2 weeks ago (appr)					
	east near Renaissance Hotel	OR 11	2 1	11 01	**2**	*593*	2 weeks ago (appr)	6 43	263	254	**259**	
	center near glassbottom boat area	OR 12	2 0	10 58	**<2**	*113*	2 weeks ago (appr)	6 40	395	410	**403**	
	central bay 100 m from shore	OR 13	10 0	11 05	**<2**	*952*	2 weeks ago (appr)					
	beach north of groin	OR 14	3 0	11 13	**3**	*30*	2 weeks ago (appr)					
	10 m off groin	OR 11	>15	11 09	**<2**		2 weeks ago (appr)					
Duplicate	(Duplicate of Station OR 12)	OR 16	2 0	10 58	**<2**	*17*	2 weeks ago (appr)					
Blank	(Pure Water Sample)	OR 15		11 42	**<2**	*103*	*(3)*	6 00	<2	<2	**<2**	

NOTES

(1) Rain started to pour heavily at 11 20h after completion of sampling of most of the stations in the bay but before sampling the streams
Turtle River had turned brownish and had some floating debris but no raw sewage Its flow rate was 0 57 m3/sec (20 cubic feet per second)

(2) The flow rate was approximately 0 7 m3/sec (25 cfs) The water was a little more brownish (i e carried more silt than during the sampling one hour earlier)
The salinity of the river water was 0 ppt the temperature was 25 deg C and the conductivity was 400 uS/cm

(3) NAYA Canadian Spring Natural Water The bottle was opened for the first time just before sampling

(4) Concentrations too high Also blank sample had a faecal coliform concentration of 103 col/100 ml when it should have been <2 col/100 ml
Therefore data are only shown for completeness but <u>cannot</u> be used for management decisions

(5) Rain fell on and off during the previous day The amount of rain at Cole Gate (6 km south of Ocho Rios) was 2 5 mm

(6) Runs 1 and 2 represent duplicate samples from a specific station collected at the same time

TNTC Too numerous too count (indicated comparatively high concentration)

No samples collected or no information

Table A 2a

Faecal Coliform Concentrations in Ocho Rios Bay (col/100 ml) *(Data)*

Turtle Beach and Sailor Hole Beach

SAMPLING EVENT 2 *28 September to 3 October 1997*

Location		Station No	Water Depth m)	Sunday 28 Sep	Monday 29 Sep			Tuesday 30 Sep			Wednesday 1 Oct			Thursday 2 Oct						Friday 3 Oct
				18 30h	6 30h		21 10h	6 45h		19 15h	7 15h*(2)*	15 10h	20 15h	6 45h				20 20h	23 15h	6 30h
				dry	dry		dry	dry		dry	dry	dry	dry	dry				dry	wet *(1)*	wet *(1)*
				Louis Berger	Louis Berger	NWC	Louis Berger	Louis Berger	NWC	Louis Berger	Louis Berger	Louis Berger	Louis Berger	Louis Berger	NWC	NRCA	Kol busch	Louis Berger	Louis Berger	Louis Berger
Sailor Hole Beach	20 m from public beach	OR 1	1 2	100	50	42	92	270		120	210		360	35	32	110	56	35	8 300	2 280
	25 m from fishermen s beach	OR 2	1 5	100	180	108	50	59		140	63		84	30	25	300	850	28	1 200	210
	western cruise ship pier	OR 4	>15	43	73	44	115	46		68	75		49	19	32			64	2,000	300
	eastern cruise ship pier	OR 5	>15	45	54	40	120	74		160	160		380	35	74	220	810	150	15 000	390
Turtle River	20 m upstream from its mouth	OR 8	0 3	2 400	1 400	1 617	2 100	2 700	3 050	2 100	1 800		3 100	1 500	3 100	>1 600	5 700	3 400	194 000	6 900
	small tributary 100 m from mouth	OR 29									<10									
	at Da Costa Drive bridge	OR 31	0 2								90									
Sailor Hole River	30 m upstream from its mouth	OR 6	0 3	770	230	230	270	220		660	330		390	620	2 676	1 600	>1 370	340	3 500	900
	spring bathing area for fishermen	OR 24	0 2	10	<10	70	0	0		13	1		1	1	9	300	270	1	20	10
	confluence with spring water	OR 28	0 2								170									
	laundry mat discharge basin	OR 30	0 1								5 600									
Turtle Beach	west near Sand Castles	OR 9	3 0	1	44	196	68	3		1	4	2	600	10	23			15	180	120
	east near Renaissance Hotel	OR 11	2 1	1	180	456	2	39		0	1	1	21	37	125			3	1 600	160
	center beach	OR 12	2 0	1	160	616	0	33	72	1	67	0	19	720	700	>1 600	>2 530	34	170	20
	central bay 100 m from shore	OR 13	10 0	1	31	30	0	36		3	270	1	530	5	10	130	116	20	490	220
	beach north of groin	OR 14	3 0	0	47	124	9	9		1	0		1	5	7			4	10	100
	10 m off groin	OR 20	>15	0	30	64	0	19		1	7	0	260	6	12			3	2 700	210
	entrance to boat harbour	OR 21		5	270	520	26	85		27	20	0	104	43	56			76	4 000	160
	end of boat pier	OR 22		4	>1 400	*ed*	9	20		5	44	900	109	110	350	>1 600	>1 730	0	1 900	440
	50m seaward from end of boat pier	OR 23		0	510	696	13	20		0	41	0	49	2	10			1	1 200	130
	center of boat harbour	OR 25									40									
	125m seaward from end of boat pier	OR 26									55	0	76	21	7			2	680	100
	eastern end of cruise ship landing	OR 27									56	2	110	7	3			1	610	210
Fern Gully channel	downstream at Main Street bridge	OR 32	0 05								4 000									
	upstream at Shell gas station	OR 33	0 05								>11 000									
Duplicates	(Duplicate) *(3)*	OR 16		0	270	504	0	34		0	74		17	50	108			37	170	50
Blank	Clean Buffer Sample	OR 15		0	0		0	0		0	0	0	0	0	<1	<2	8	0	0	0

NOTES

(1) Rain fell on October 2 between 21 00 and 22 30h total rain amount was 20 mm
The samples collected during the following morning are also considered wet weather samples

(2) Stations OR 1 to OR 27 were collected between 7 00h and 7 30h stations OR 28 to OR 34 were collected between 7 30h and 8 45h

(3) Duplicate stations OR 16 was a duplicate always of OR 12 with the exception of 9/28pm (dupl of OR 14) and 10/2am (dupl of OR 11)

ed Edited due to apparent analytical error

Not available or not applicable

FC SEP97 XLS 1/7/98 9 27 PM

Table A 2b

Faecal Coliform Concentrations in Ocho Rios Bay (col/100 ml) *(Statistics)*

Turtle Beach and Sailor Hole Beach

SAMPLING EVENT 2 *28 September to 3 October 1997*

Location		Station No	STATISTICS: Geom Mean (dry weather only, all Berger samples)	Count (dry weather only, all Berger samples)	Minimum (dry weather only, all Berger samples)	Maximum (dry weather only, all Berger samples)	Geom Mean (dry and wet weather, all Berger samples)	Count (dry and wet weather, all Berger samples)	Minimum (dry and wet weather, all Berger samples)	Maximum (dry and wet weather, all Berger samples)
Sailor Hole Beach	20 m from public beach	OR 1	**104**	9	35	360	**204**	11	35	8 300
	25 m from fishermen s beach	OR 2	**68**	9	28	180	**98**	11	28	1 200
	western cruise ship pier	OR 4	**56**	9	19	115	**90**	11	19	2 000
	eastern cruise ship pier	OR 5	**101**	9	35	380	**180**	11	35	15 000
Turtle River	20 m upstream from its mouth	OR 8	**2 186**	9	1 400	3 400	**3 648**	11	1 400	194 000
	small tributary 100 m from mouth	OR 29	**5**	1			**5**	1		
	at Da Costa Drive bridge	OR 31	**90**	1			**90**	1		
Sailor Hole River	30 m upstream from its mouth	OR 6	**386**	9	220	770	**509**	11	220	3 500
	spring bathing area for fishermen	OR 24	**2**	9	0	13	**3**	11	0	20
	confluence with spring water	OR 28	**170**	1			**170**	1		
	laundry mat discharge basin	OR 30	**5 600**	1			**5 600**	1		
Turtle Beach	west near Sand Castles	OR 9	**10**	10	1	600	**15**	12	1	600
	east near Renaissance Hotel	OR 11	**5**	10	0	180	**11**	12	0	1 600
	center beach	OR 12	**11**	10	0	720	**15**	12	0	720
	central bay 100 m from shore	OR 13	**11**	10	0	530	**19**	12	0	530
	beach north of groin	OR 14	**3**	9	0	47	**5**	11	0	100
	10 m off groin	OR 20	**4**	10	0	260	**10**	12	0	2 700
	entrance to boat harbour	OR 21	**28**	10	0	270	**49**	12	0	4 000
	end of boat pier	OR 22	**32**	10	0	1 400	**56**	12	0	1 900
	50m seaward from end of boat pier	OR 23	**6**	10	0	510	**12**	12	0	1 200
	center of boat harbour	OR 25	**40**	1			**40**	1		
	125m seaward from end of boat pier	OR 26	**10**	5	0	76	**25**	7	0	680
	eastern end of cruise ship landing	OR 27	**10**	5	1	110	**27**	7	1	610
Fern Gully channel	downstream at Main Street bridge	OR 32	**4 000**	1			**4 000**	1		
	upstream at Shell gas station	OR 33	**11 000**	1			**11 000**	1		
Duplicates	(Duplicate) *(3)*	OR 16								
Blank	Clean Buffer Sample	OR 15								

Table A 3a

Faecal Colıform Concentratıons ın Ocho Rıos Bay (col/100 ml) *(Data)*

Turtle Beach and Saılor Hole Beach

SAMPLING EVENT 3 26 October to 2 November 1997

Location		Station No	Water Depth (appr m)	Sunday 26 Oct 14 00h dry Louis Berger	Monday 27 Oct 6 25h dry Louis Berger	Monday 27 Oct 6 25h NWC	Monday 27 Oct 20 40h dry Louis Berger	Tuesday 28 Oct 6 30h dry Louis Berger	Tuesday 28 Oct 6 30h NWC	Tuesday 28 Oct 19 20h dry Louis Berger	Wednesday 29 Oct 7 30 to 8 45h dry Louis Berger	Wednesday 29 Oct 7 30 to 8 45h NWC	Wednesday 29 Oct 7 30 to 8 45h NRCA	Wednesday 29 Oct 7 30 to 8 45h Kol busch	Wednesday 29 Oct 18 35h dry Louis Berger	Thursday 30 Oct 7 35h dry Louis Berger	Thursday 30 Oct 7 35h NWC	Thursday 30 Oct 22 15h dry Louis Berger	Friday 31 Oct 6 30h dry Louis Berger	Friday 31 Oct 10 45h dry/ wet*(1)* NWC
Sailor Hole Beach	20 m from public beach	OR 1	1 2	320	140	70	150	150	68	38	112	250	80	>340	60	128	76	890	81	420
	25 m from fishermen s beach	OR 2	1 5	12	42	27	47	160	56	40	61	138	80	>2 415	240	90	118	52	42	438
	western cruise ship pier	OR 4	>15	3 220	170		700	51		2 600	72	60			1 500	900		1 900	210	380
	eastern cruise ship pier	OR 5	>15	1 740	680	450	370	450		70	31	30	110	>665	60	130	270	1 020	109	104
Turtle River	20 m upstream from its mouth	OR 8	0 3	>20 000	31 400	33 636	16 000	2 500	2 342	44 000	15 000	17 818	>1 600	>7 300	23 000	28 000	40 000	40 000	7 700	7 727
	small tributary 100 m from mouth	OR 29																		
	at Da Costa Drive bridge	OR 31	0 2																	
Sailor Hole River	30 m upstream from its mouth	OR 6	0 3	120	430	90	560	530		420	350	730	280	>965	580	130		660	300	400
	spring bathing area for fishermen	OR 24	0 2	2	264					0	17	27			0					
	confluence with spring water	OR 28	0 2																	
	laundry mat discharge basin	OR 30	0 1																	
Turtle Beach	west near Sand Castles	OR 9	3 0	<2	2		200	1		4	0	2	<2	>55	13	12		6	6	116
	east near Renaissance Hotel	OR 11	2 1	<2	2		150	5	10	7	0	<1			1	21		12	28	62
	center beach	OR 12	2 0	<2	10	20	16	6	8	2	4	5	15	253	2	20	48	2	142	<1
	central bay 100 m from shore	OR 13	10 0	<2	45		12	3		1	0	<1			87	25		57	21	<1
	beach north of groin	OR 14	3 0	<2	4		13	123		6	1	2			0	0		8	4	
	10 m off groin	OR 20	>15	<2	36		14	83		0	0	3			6	<10		540	6	
	entrance to boat harbour	OR 21		<2	28		53	12		23	110	125			12	61		40	15	7
	end of boat pier	OR 22		1 000	120		170	27		110	200	500			1 360	29		10 000	360	3 433
	50m seaward from end of boat pie	OR 23		<2	3		5	5	38	3	0	2			34	100		76	120	2
	center of boat harbour	OR 25																		
	125m seaward from end of boat pi	OR 26		<2	7		49	30		22	0	<1			8	49		25	120	
	eastern end of cruise ship landing	OR 27		<2	14		54	87		7	11	23			23	<10		16	9	
Fern Gully channel	downstream at Main Street bridge	OR 32	0 05																	
	upstream at Shell gas station	OR 33	0 05																	
Duplicates	(Duplicate) *(2)*	OR 16		60	1		8	64		1	56	27	130	>590	28	117	250	1 020	150	208
	(duplicate of OR 1)	OR 1											130	>1 480						
Blank	(Boiled Seawater)	OR 15									0	<1	<2	0						

NOTES *(1)* Small amount of rain between 7 00h and 8 30h Rain volume in downtown Ocho Rios was 0 02

(2) Duplicate stations 10/26 OR 1 10/27am OR 23 10/27pm OR 23 10/28am OR 5 10/28pm OR 23
10/29am OR 4 10/29pm OR 4 10/30am OR 4 10/30pm OR 5 10/31am OR 12 10/31mid day OR 4

Not available or not applicable

Table A 3b

Faecal Coliform Concentrations in Ocho Rios Bay (col/100 ml) *(Statistics)*

Turtle Beach and Sailor Hole Beach

SAMPLING EVENT 3 26 October to 2 November 1997

Location		Station No	STATISTICS: Geom Mean	Count	Mini mum	Maxi mum
			dry weather only all Berger samples			
Sailor Hole Beach	20 m from public beach	OR 1	**137**	10	38	890
	25 m from fishermen s beach	OR 2	**58**	10	12	240
	western cruise ship pier	OR 4	**536**	10	51	3 220
	eastern cruise ship pier	OR 5	**227**	10	31	1 740
Turtle River	20 m upstream from its mouth	OR 8	**17 853**	10	2 500	44 000
	small tributary 100 m from mouth	OR 29				
	at Da Costa Drive bridge	OR 31				
Sailor Hole River	30 m upstream from its mouth	OR 6	**357**	10	120	660
	spring bathing area for fishermen	OR 24	**5**	5	0	264
	confluence with spring water	OR 28				
	laundry mat discharge basin	OR 30				
Turtle Beach	west near Sand Castles	OR 9	**5**	10	0	200
	east near Renaissance Hotel	OR 11	**6**	10	0	150
	center beach	OR 12	**6**	10	1	142
	central bay 100 m from shore	OR 13	**9**	10	0	87
	beach north of groin	OR 14	**4**	10	0	123
	10 m off groin	OR 20	**8**	10	0	540
	entrance to boat harbour	OR 21	**21**	10	1	110
	end of boat pier	OR 22	**265**	10	27	>10 000
	50m seaward from end of boat pier	OR 23	**9**	10	0	120
	center of boat harbour	OR 25				
	125m seaward from end of boat pier	OR 26	**13**	10	0	120
	eastern end of cruise ship landing	OR 27	**14**	9	1	87
Fern Gully channel	downstream at Main Street bridge	OR 32				
	upstream at Shell gas station	OR 33				
Duplicates	(Duplicate) *(2)*	OR 16				
	(duplicate of OR 1)	OR 1				
Blank	(Boiled Seawater)	OR 15				

Table A 4

Faecal Coliform Concentrations in Ocho Rios Bay (col/100 ml)

Turtle Beach and Sailor Hole Beach

SAMPLING EVENT 4 December 7 to 12 1997

Location		Station No	Water Depth m)	Sunday 7 Dec		Monday 8 Dec			Tuesday 9 Dec			Wedn 10 Dec	Thursday 11 Dec		Friday 12 Dec	STATISTICS			
				12 30h dry	19 15h dry *(1)*	6 35h dry *(1)*		19 45h dry *(1)*	6 50h dry		19 00h dry	17 50h dry	6 25h dry		7 20h dry	Geom Mean	Count	Minimum	Maximum
				Louis Berger	Louis Berger	Louis Berger	NWC	Louis Berger	Louis Berger	NWC	Louis Berger	Louis Berger	Louis Berger	NWC	Louis Berger	dry weather all Berger samples			
Sailor Hole Beach	20 m from public beach	OR 1	1 2	0	36	38	60	190	460	*ed*	790	30	21	*ed*	260	58	9	0	790
	25 m from fishermen s beach	OR 2	1 5	0	14 800	150		590	570		270	58	310	*ed*	470	211	9	0	14 800
	western cruise ship pier	OR 4	>15	77		45	23	6 400	280	*ed*	56	230	53	*ed*	400	190	8	45	6 400
	eastern cruise ship pier	OR 5	>15	45		86	86	23 000	230		360	40	12		830	203	8	12	23 000
Turtle River	20 m upstream from its mouth	OR 8	0 3	12,700	7,000	4 200	650	18 000	5,100	*ed*	11 000	6 000	2,100	*ed*	23 000	7 819	9	2 100	23 000
	small tributary 100 m from mouth	OR 29																	
	at Da Costa Drive bridge	OR 31	0 2																
Sailor Hole River	30 m upstream from its mouth	OR 6	0 3	820	320	380		550	3 900		1 040	360	370		3,000	764	9	320	3 900
	spring bathing area for fishermen	OR 24	0 2	0		2		3				2				2	4	0	3
	confluence with spring water	OR 28	0 2																
	laundry mat discharge basin	OR 30	0 1																
Turtle Beach	west near Sand Castles	OR 9	3 0	29		4		20	130		7	24	36		48	23	8	4	130
	east near Renaissance Hotel	OR 11	2 1	21		<2		58	3		2	0	5		60	6	8	0	60
	center beach	OR 12	2 0	0		4	25	1	230	*ed*	0	1	250	*ed*	72	7	8	0	250
	central bay 100 m from shore	OR 13	10 0	0		6		260	65		1	0	66		80	10	8	0	260
	beach north of groin	OR 14	3 0	2		<2		1	130		0	2	0		0	2	8	0	130
	10 m off groin	OR 20	>15	1		6		1	31		0	2	3		40	3	8	0	40
	entrance to boat harbour	OR 21		2		2		210	17		37	77	22		25	20	8	2	210
	end of boat pier	OR 22		11		1,100		17 900	180	*ed*	3,200	2	6		83	137	8	2	17 900
	50m seaward from end of boat pier	OR 23		0		<2	22	640	6		7	2	26		89	9	8	0	640
	center of boat harbour	OR 25																	
	125m seaward from end of boat pie	OR 26		0		6		24	24		2	0	54		99	7	8	0	99
	eastern end of cruise ship landing	OR 27		0		6		1	43		19	1	123		55	8	8	0	123
Fern Gully channel	downstream at Main Street bridge	OR 32	0 05																
	upstream at Shell gas station	OR 33	0 05																
Duplicates	(Duplicate) *(2)*	OR 16		17		24		500	15		1	50	89		63				
Blank	(Boiled Seawater Sample)	OR 15																	

NOTES

(1) Rain in the mountains south of Ocho Rios on Sunday The rain rate at Cole Gate (6 km south) were 12 mm the rate at Walker s Wood was 41 mm

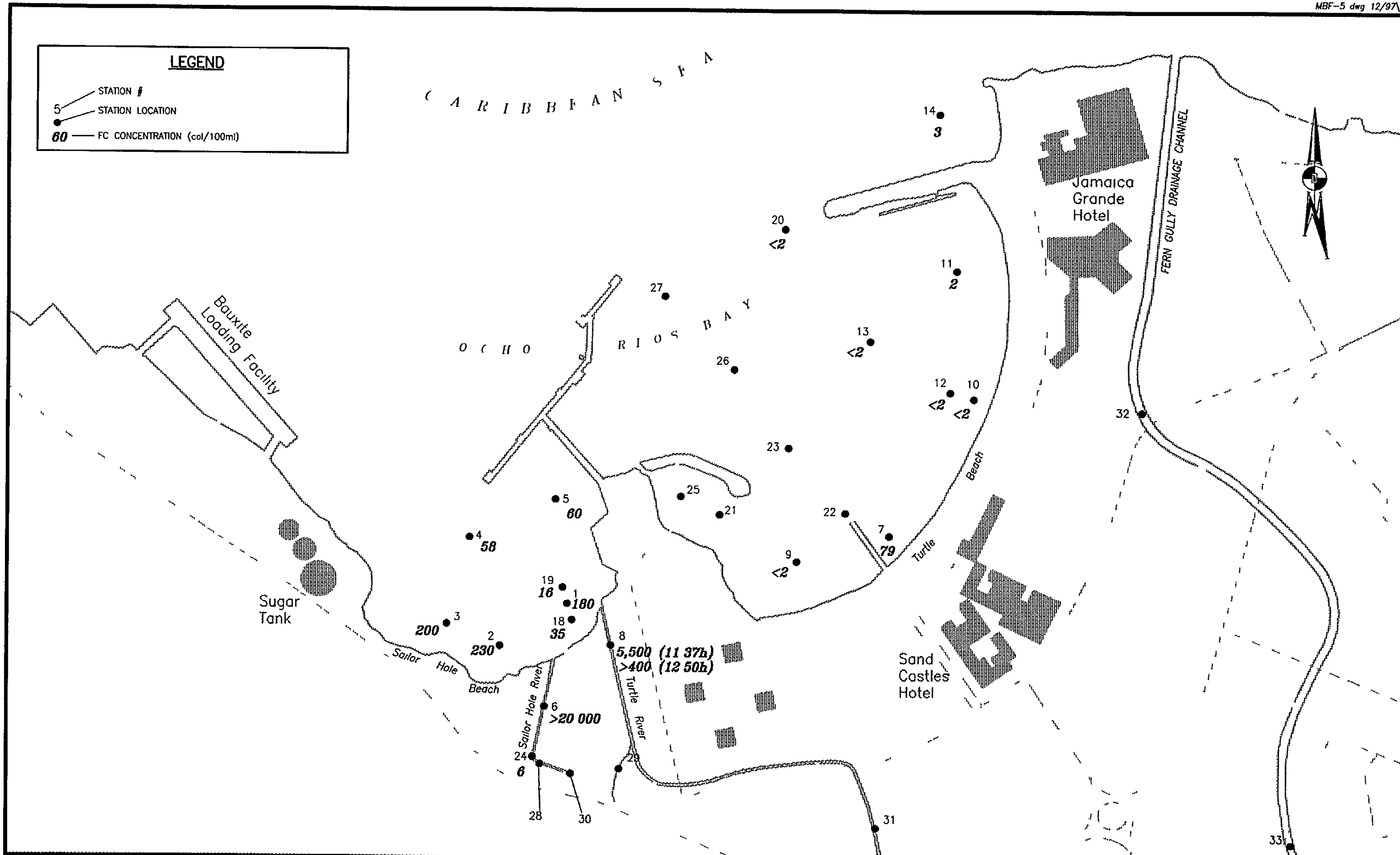
(2) Duplicate stations 12/7noon OR 4 12/8am OR 4 12/8pm OR 4 12/9am OR 4 12/9pm OR 12 12/10pm OR 4 12/11am OR 13 12/12am OR 12

ed Edited due to quality control problems

Not available or not applicable

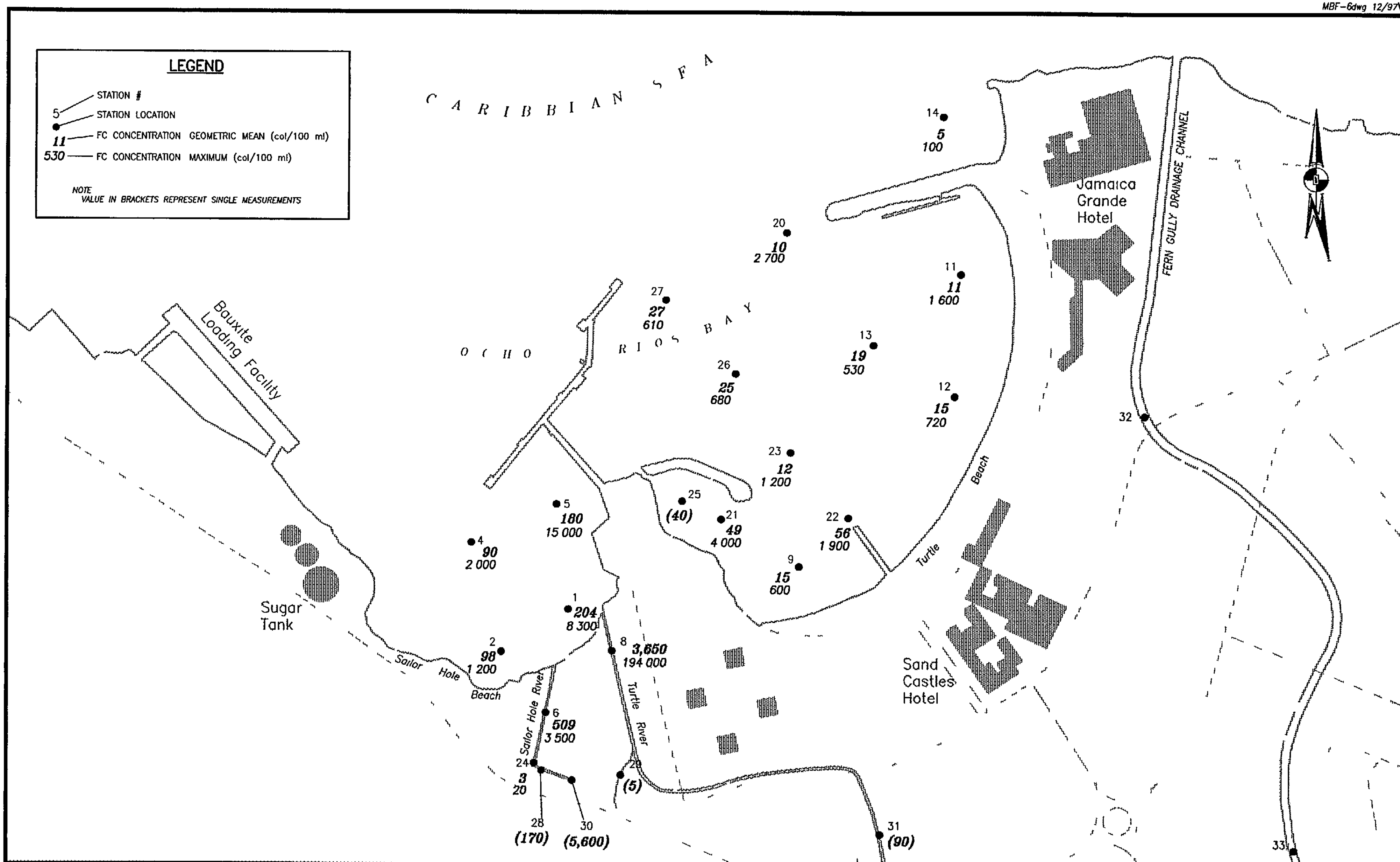
FC DEC97 XLS 1/7/98 9 59 PM

MBF-5 dwg 12/97\A.G

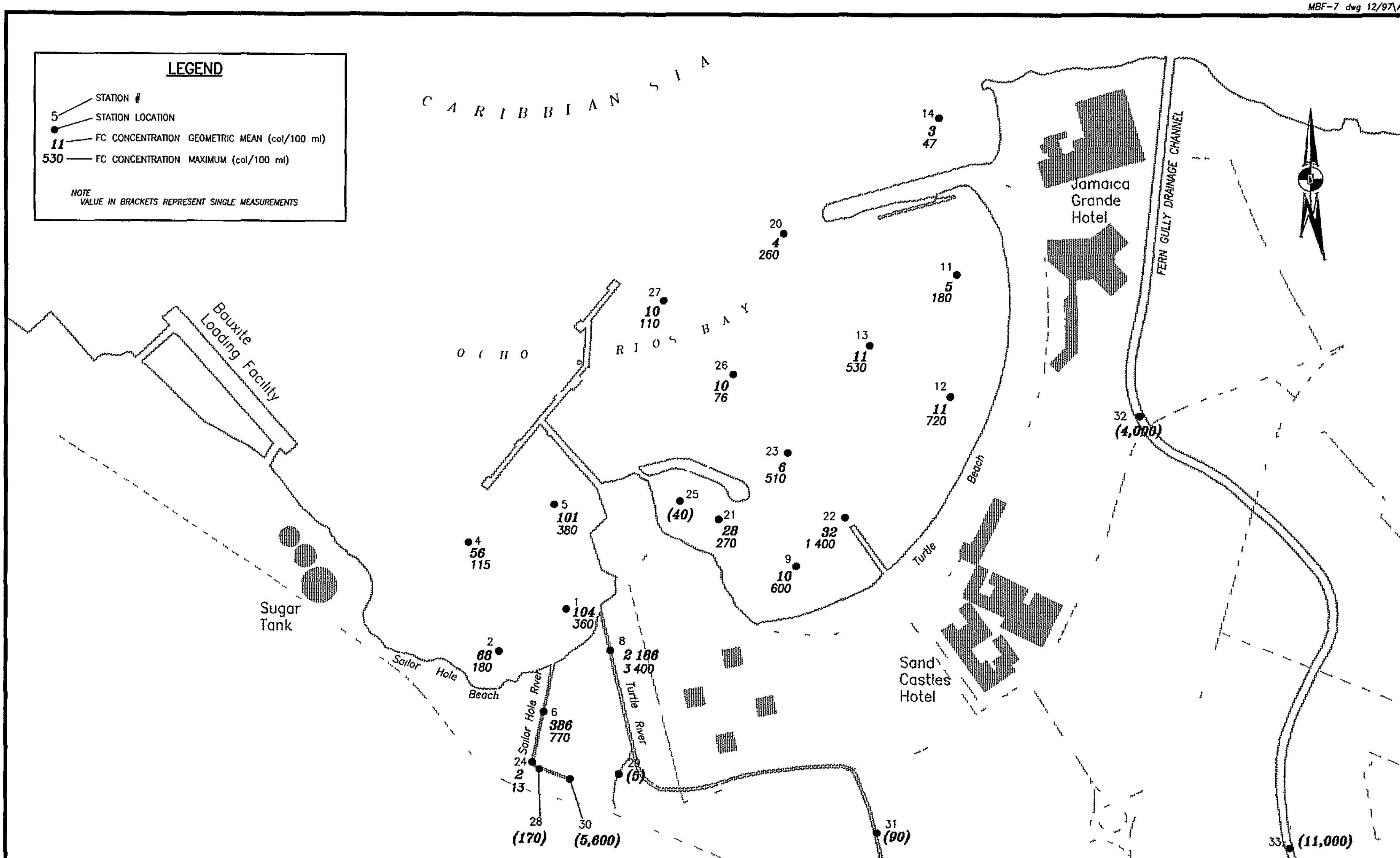


US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure A-1
LOUIS BERGER INTERNATIONAL, INC Technical Support Services, Inc	Approximate Scale 1cm = 120 meters December 1997	OCHO RIOS - Faecal Coliform (All Samples) Sampling Event 1 Aug 26, 1997

MBF-6dwg 12/97\AG

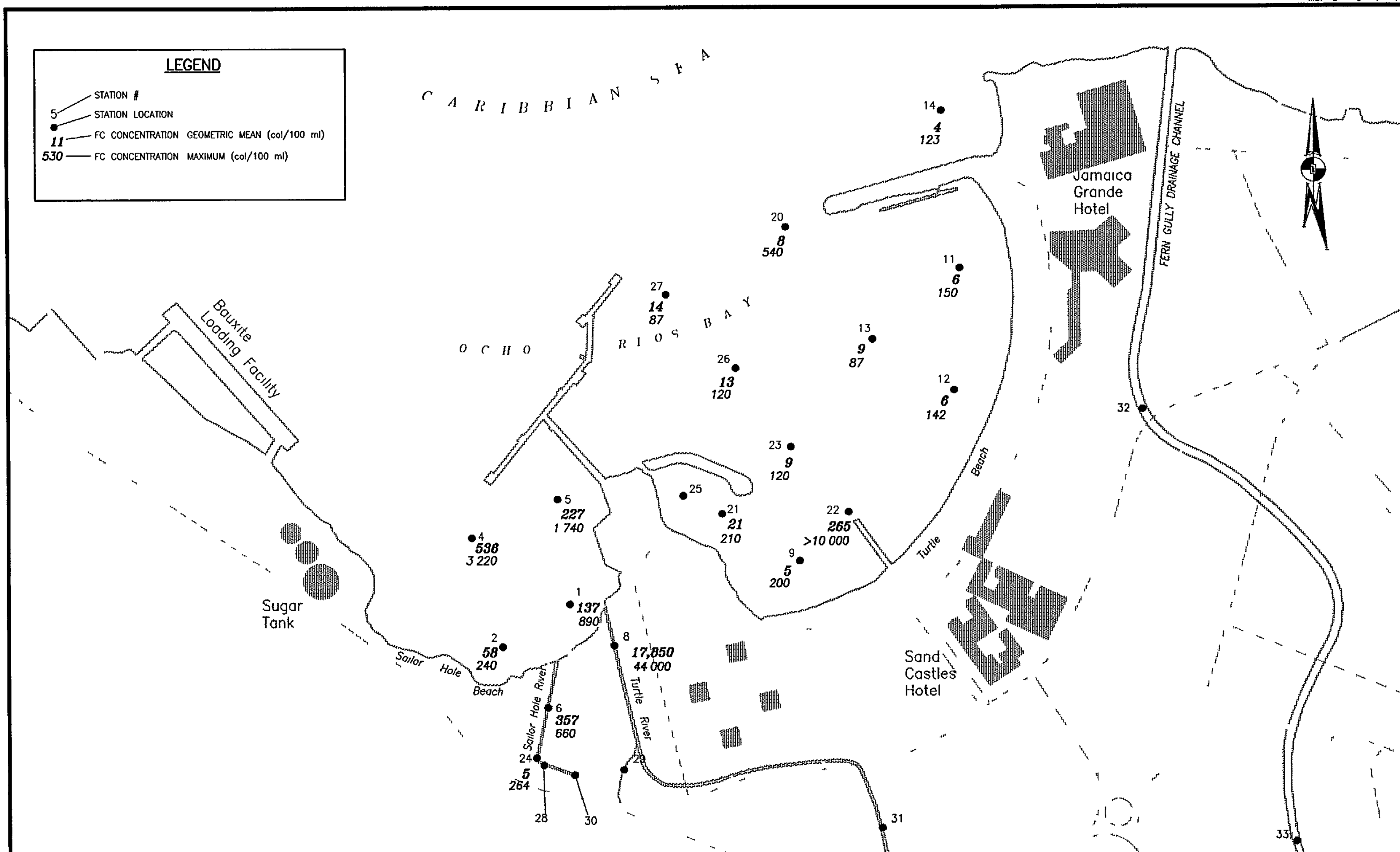


US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure A-2a
LOUIS BERGER INTERNATIONAL, INC Technical Support Services, Inc	Approximate Scale 1cm = 120 meters December 1997	OCHO RIOS - Faecal Coliform (All Samples) Sampling Event 2. Sept. 28 to Oct 3, 1997



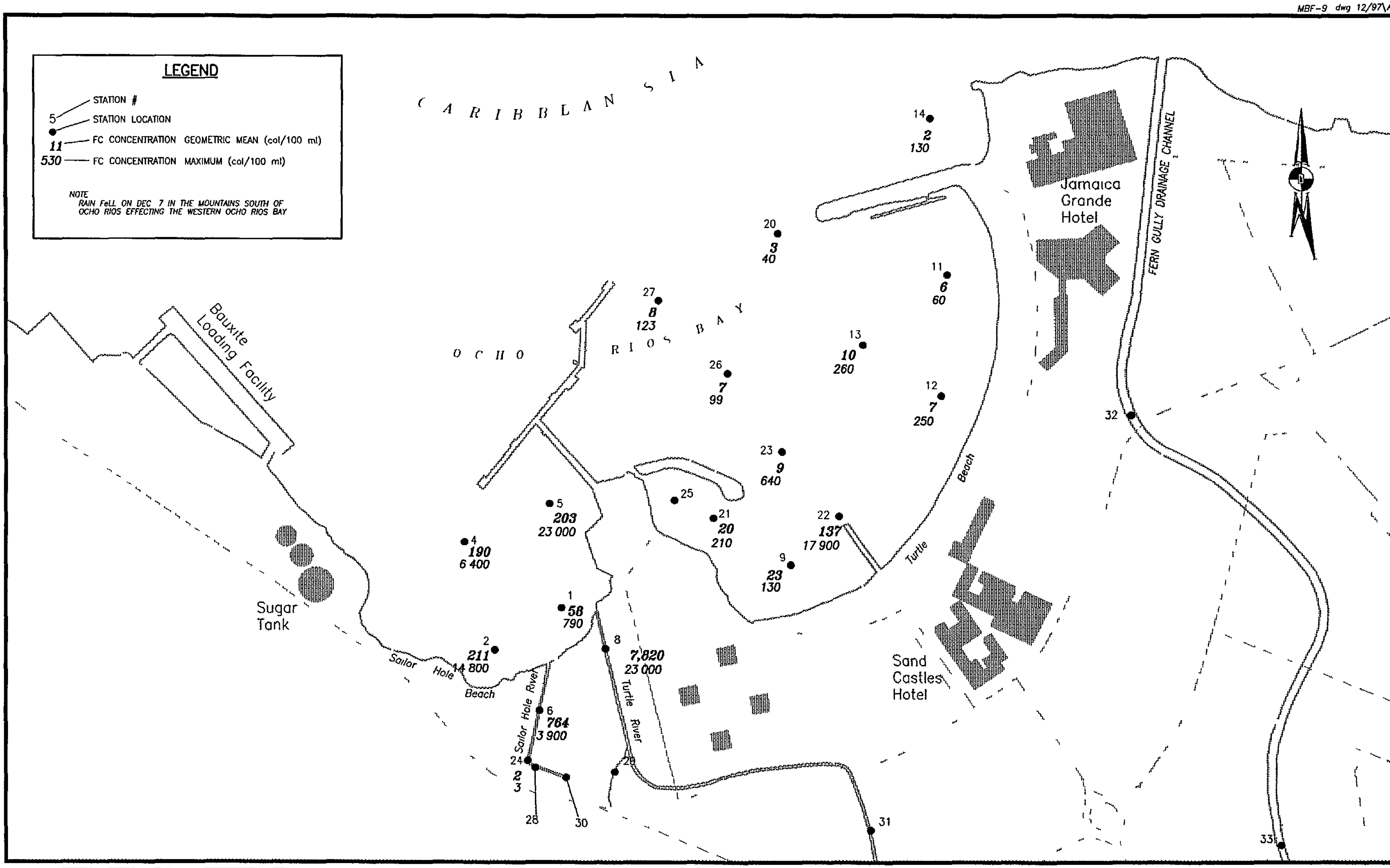
US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure A-2b
LOUIS BERGER INTERNATIONAL, INC Technical Support Services, Inc	Approximate Scale 1cm = 120 meters	OCHO RIOS - Faecal Coliform (Dry Weather)
	December 1997	Sampling Event 2 Sept 28 to Oct 3, 1997

MBF-8 dwg 12/97\A.G



US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure A-3
LOUIS BERGER INTERNATIONAL, INC Technical Support Services, Inc	Approximate Scale 1cm = 120 meters	OCHO RIOS - Faecal Coliform (All Samples)
	December 1997	Sampling Event 3 Oct. 26 to Nov 2, 1997

MBF-9 dwg 12/97\A.G



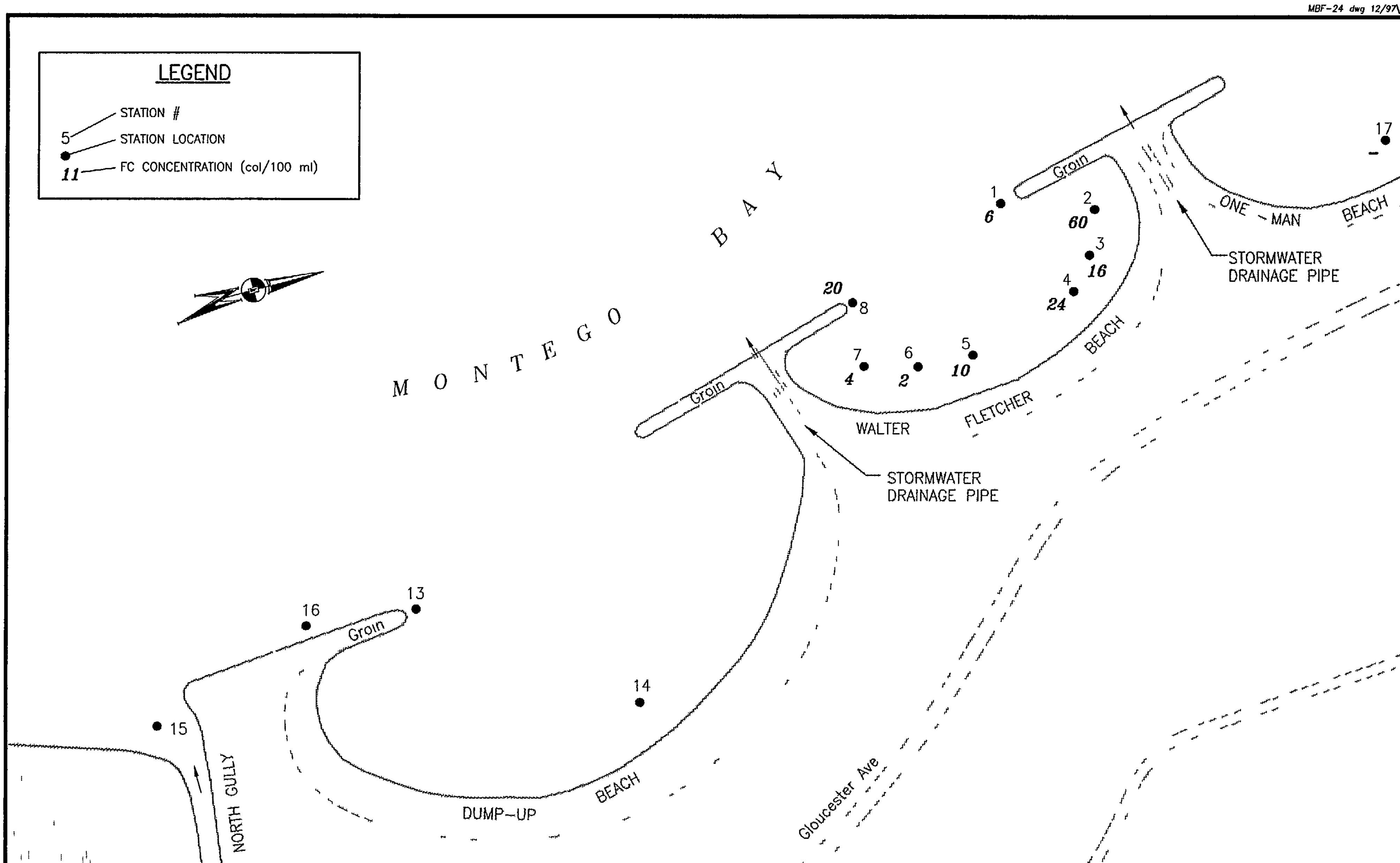
US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure A-4
LOUIS BERGER INTERNATIONAL, INC Technical Support Services, Inc	Approximate Scale 1cm = 120 meters	OCHO RIOS - Faecal Coliform (All Samples)
	December 1997	Sampling Event 4 Dec 7 to Dec 12, 1997

ATTACHMENT B

Faecal Coliform Concentrations and Distribution by Sampling Event:

MONTEGO BAY

(Walter Fletcher Beach, and Surrounding Areas)



US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure B-1
LOUIS BERGER INTERNATIONAL, INC Technical Support Services, Inc	Scale 1cm = 40 meters December 1997	MONTEGO BAY - Faecal Coliform (Concentrations) Sampling Event 1 (Reconnaissance) Aug 28, 1997

Table B-1

Faecal Coliform Concentrations in Montego Bay (col/100 ml)

Walter Fletcher Beach

SAMPLING EVENT 1 (Reconnaissance) August 26 to 29 1997

Location		Station No	Water Depth *(appr m)*	Sampl Time *(h)*	Thursday **28 Aug** Faecal Coliform Concen-tration *(col/100 ml)* NWC Lab	Rainfall	Notes
Walter	at northern groin entrance to beach	MB- 1	0 3	12 24	**6**	Heavy rainfall during the afternoon of	
Fletcher	northern corner	MB- 2	1 1	12 36	**60**	the previous day (rainfall rate 23 mm)	(1)
Beach	northeastern corner	MB- 3	1 5	12 41	**16**	Walter Fletcher Beach was closed	
	center north	MB- 4	1 6	12 30	**24**	during the evening following the	
	center south	MB- 5	1 6	12 40	**10**	rain storm (the beach is usually open until	
	southeastern corner	MB- 6	1 5	12 49	**2**	22 00h The cause given for the beach	
	southern corner	MB- 7	1 0	12 53	**4**	closure was floating debris	
	at southern groin entrance to beach	MB- 8	0 3	13 06	**20**		
Duplicate	(duplicate of Stn 7)	MB- 9	1 0	12 53	**12**		

NOTES

(1) Remaining floating debris was a concentrated in this area incl some sewage

Table B-2

Faecal Coliform Concentrations in Montego Bay (col/100 ml)

Walter Fletcher Beach

SAMPLING EVENT 2   28-September to 3-October 1997

Location		Station No	Water Depth (appr m)	Monday 29 Sep 11 00h dry Louis Berger	Monday 29 Sep 11 00h dry NWC	Monday 29 Sep 17 45h dry Louis Berger	Tuesday 30 Sep 10 00h dry Louis Berger	Tuesday 30 Sep 10 00h dry NWC	Tuesday 30 Sep 16 45h dry Louis Berger	Thursday 2 Oct 11 40h dry (1) Louis Berger	Thursday 2 Oct 11 40h dry (1) NWC	Thursday 2 Oct 16 50h dry Louis Berger	Friday 3 Oct 10 00h dry/wet (2) NWC	STATISTICS (dry and wet weather, All Berger samples & NWC samples from Oct 3) Geom Mean	Count	Minimum	Maximum
Walter Fletcher Beach	northern corner	MB 2	1 1	**0**		**0**	**5**	3	**0**	**0**		**0**	28	**1**	7	0	28
	center north	MB 4	1 6	**0**		**0**	**1**	3	**0**	**0**		**1**	22	**1**	7	0	22
	center south	MB 5	1 6	**0**		**1**	**4**	13	**0**	**0**		**0**	10	**1**	7	0	10
	southern corner	MB 7	1 0	**1**	4	**0**	**0**	1	**0**	**0**	<1	**1**	2	**1**	7	0	2
	at southern groin entrance to beach	MB 8	0 3	**3**		**0**	**6**	5	**2**	**2**		**17**	232	**5**	7	0	232
Dump up Beach	at southern groin entrance to beach	MB 13	0 3	**1**		**9**	**10**	15	**0**	**1,700**		**151**	707	**26**	7	0	1 700
	center of beach	MB 14	1 2	**0**		**0**	**4**	<1	**0**	**4**		**17**	5	**2**	7	0	17
North Gully	between N Gully and Dump up Beach	MB 16	0 3														
	10 m seaward from mouth	MB 15	0 3										1 200	**1,200**	1		
One man Beach	center of beach	MB 17	1 2														
Duplicates	(duplicate of Stn MB 7)	MB 9	1 0	**0**			**0**	<1		**0**			7	**1**	4	0	7

NOTES

(1) A trace amount of rain fell during the previous night some garbage was noticed floating on the ocean around the mouth of North Gully According to local residents the flow in North Gully was not excessive however

(2) Rain during the previous night 11 9 mm) some floating garbage around the mouth of North Gully

Not available or not applicable

Table B 3

Faecal Coliform Concentrations in Montego Bay (col/100 ml)
Walter Fletcher Beach

SAMPLING EVENT 3 26 October to 2 November 1997

Location		Station No	Water Depth (appr m)	Sunday 26 Oct 17 40h dry	Monday (3) 27 Oct 9 45h dry (2)		Tuesday 28 Oct 10 15h dry (2)		Wedn 29 Oct 14 15h dry	Thursday 30 Oct 18 15h dry	Friday 31 Oct 14 25h dry	STATISTICS dry weather all Berger samples & NWC samples from Oct 31				STATISTICS dry weather all Berger samples (except Oct 27 & 28) & NWC samples from Oct 31			
				Louis Berger	Louis Berger	NWC	Louis Berger	NWC	Louis Berger	Louis Berger	NWC	Geom Mean	Count	Minimum	Maximum	Geom Mean	Count	Minimum	Maximum
Walter	northern corner	MB 2	1 1	**10**	***>6 000***		**940**		**0**	**0**	37	**28**	6	0	>6 000	**3**	4	0	37
Fletcher	center north	MB 4	1 6	**11**	***>6 000***		**140**		**0**	**0**	<1	**10**	6	0	>6 000	**1**	4	0	11
Beach	center south	MB 5	1 6	**12**	***>6 000***	1 040	**520**	900	**0**	**0**	10	**21**	6	0	>6 000	**2**	4	0	12
	southern corner	MB 7	1 0	**2**	**0**		**20**		**0**	**0**	10	**2**	6	0	20	**1**	4	0	10
	at southern groin entrance to beach	MB 8	0 3	**3**	***>6 000***	220	**47**		**0**	**1**	42	**16**	6	0	>6 000	**3**	4	0	42
Dump up	at southern groin entrance to beach	MB 13	0 3	**45**	**50**	450	**153**	490	**4**	**0**	13	**14**	6	0	153	**6**	4	0	45
Beach	center of beach	MB 14	1 2	**2**	**5**	17	**1**	5	**0**	**1**	<1	**1**	6	0	5	**1**	4	0	2
North Gully	between N Gully and Dump up Beach	MB 16	0 3	**290**	**150**		**670**		**3**	**1**	18	**34**	6	1	670	**11**	4	1	290
	10 m seaward from mouth	MB 15	0 3	**>10 000**	**58 000**		**4 000**	4 360	**7 600**	**20 000**	4 800	**10 917**	6	4 000	58 000	**9 242**	4	4 800	20 000
One man Beach	center of beach	MB 17	1 2																
Duplicates	(Duplicate) *(1)*	MB 9	1 0	**1**	***>6 000***		**52**		**1**	**0**	2								

NOTES

(1) Duplicate stations 10/26 MB 8 10/27 MB 8 10/28 MB 8 10/29 MB 14 10/30 MB 5 10/31 MB 5

(2) The cause for the high concentrations is not known

(3) The data for Walter Fletcher Beach (in italics) represent best estimates since the concentrations of coliform colonies on the filter were too numerous to count

Not available or not applicable

Table B 4

Faecal Coliform Concentrations in Montego Bay (col/100 ml)
Walter Fletcher Beach

SAMPLING EVENT 4 December 7 to 12 1997

Location		Station No	Water Depth (appr m)	Sunday 7 Dec 16 00h dry Louis Berger	Monday 8 Dec 17 00h dry Louis Berger	Tuesday 9 Dec 16 00h dry Louis Berger	Wednesday 10 Dec 12 00h dry Louis Berger	NWC (MF)	NWC (MT)	NRCA	Thursday 11 Dec 17 10h dry Louis Berger	STATISTICS dry weather all Berger samples Geom Mean	Count	Minimum	Maximum
Walter Fletcher Beach	northern corner	MB 2	1 1	**1**	**0**	**1**	**1**				**0**	**1**	5	0	1
	center north	MB 4	1 6	**7**	**2**	**12**	**2**				**1**	**3**	5	1	12
	center south	MB 5	1 6	**4**	**1**	**1**	**2**	*ed*	2	220	**0**	**1**	5	0	4
	southern corner	MB 7	1 0	**9**	**2**	**0**	**1**				**0**	**1**	5	0	9
	at southern groin entrance to beach	MB 8	0 3	**0**	**0**	**3**	**0**				**0**	**1**	5	0	3
Dump up Beach	at southern groin entrance to beach	MB 13	0 3		**0**	**3**	**0**				**0**	**1**	4	0	3
	center of beach	MB 14	1 2	**0**	**5**	**0**	**1**	*ed*		110	**1**	**1**	5	0	5
North Gully	between N Gully and Dump up Beach	MB 16	0 3	**3**	**4**	**5**	**1**	*ed*	940	>1 600	**1**	**2**	5	1	5
	10 m seaward from mouth	MB 15	0 3	**22 700**	**36 000**	**3,160**	**>40 000**	*ed*		>16 000	**13,400**	**16,914**	5	3 160	>40 000
One man Beach	center of beach	MB 17	1 2			**1**					**0**	**1**	2		
Duplicates	(Duplicate) *(1)*	MB 9	1 0	**6**	**0**	**1**	**0**	*ed*		130	**1**				
	Duplicate of MB 16	MB 16a	0 3				**0**			350					
	Clean Buffer Solution	Buffer					**0**	*ed*		<2					

NOTES

(1) Duplicate stations 12/7 MB 7 12/8 MB 14 12/9 MB 14 12/10 MB 5 12/11 MB 16

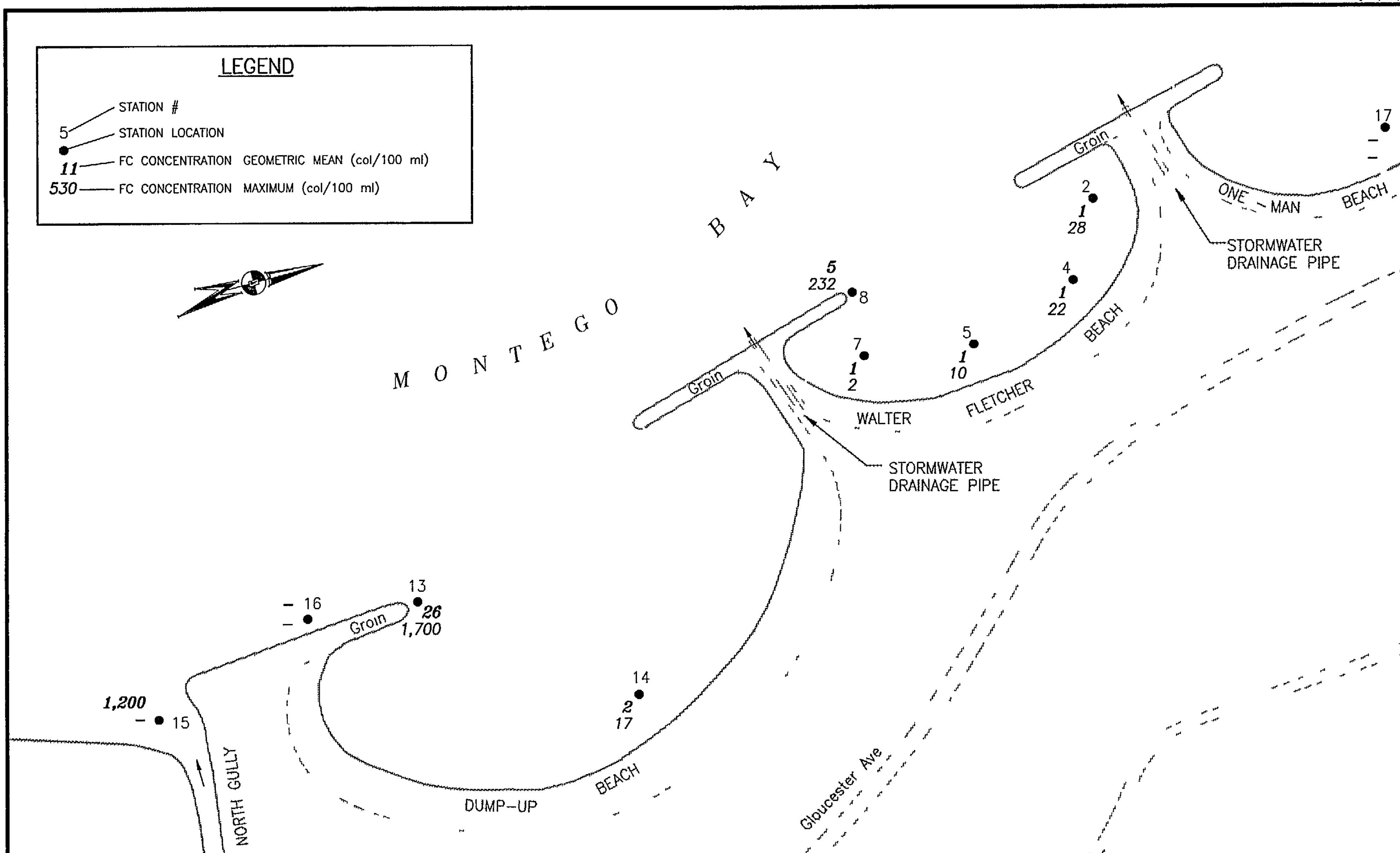
MT Multiple Tube Method

MF Membrane Filtration Method

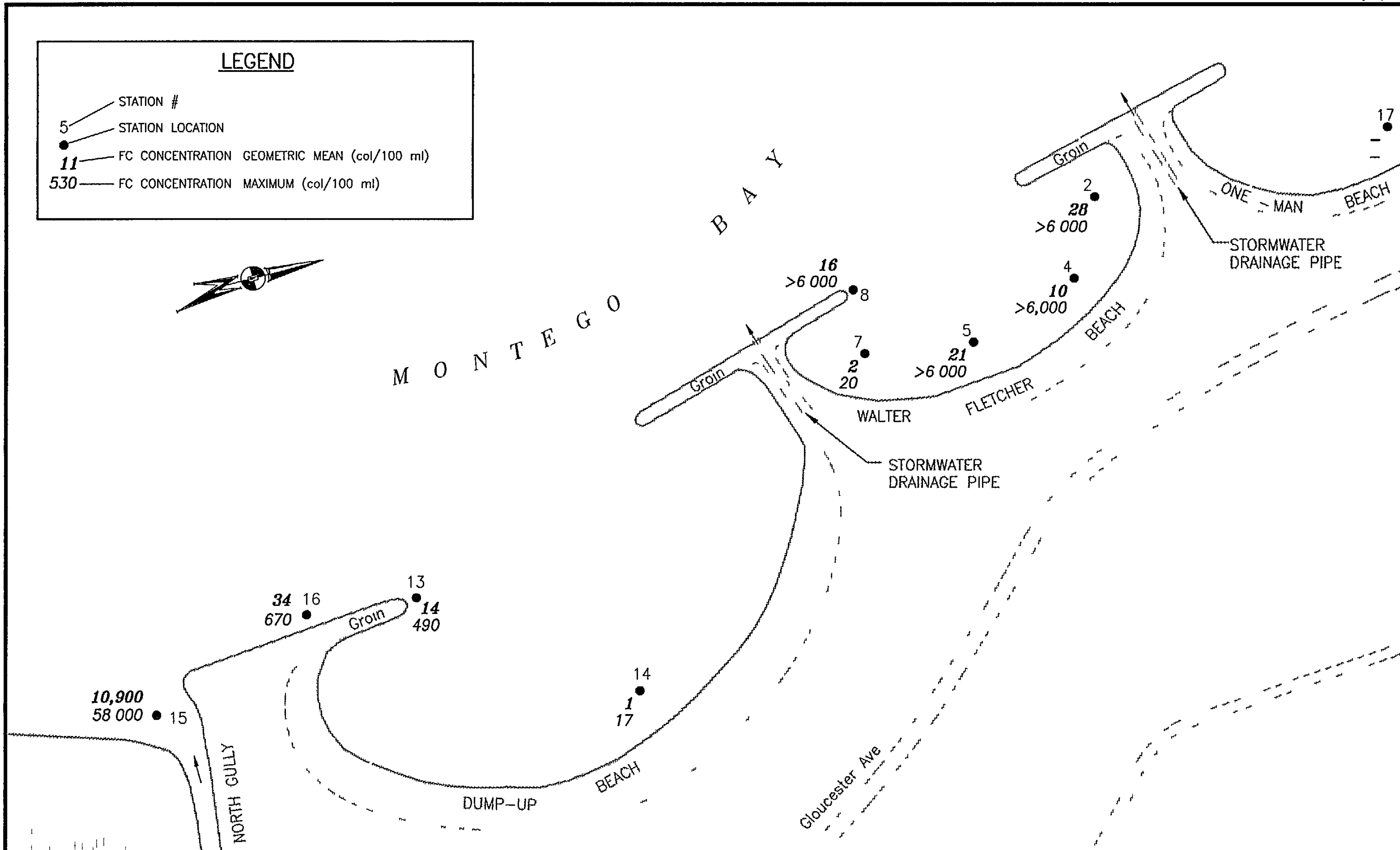
ed Edited due to quality control problems

Not available or not applicable

MBF-25 dwg 12/97\AG

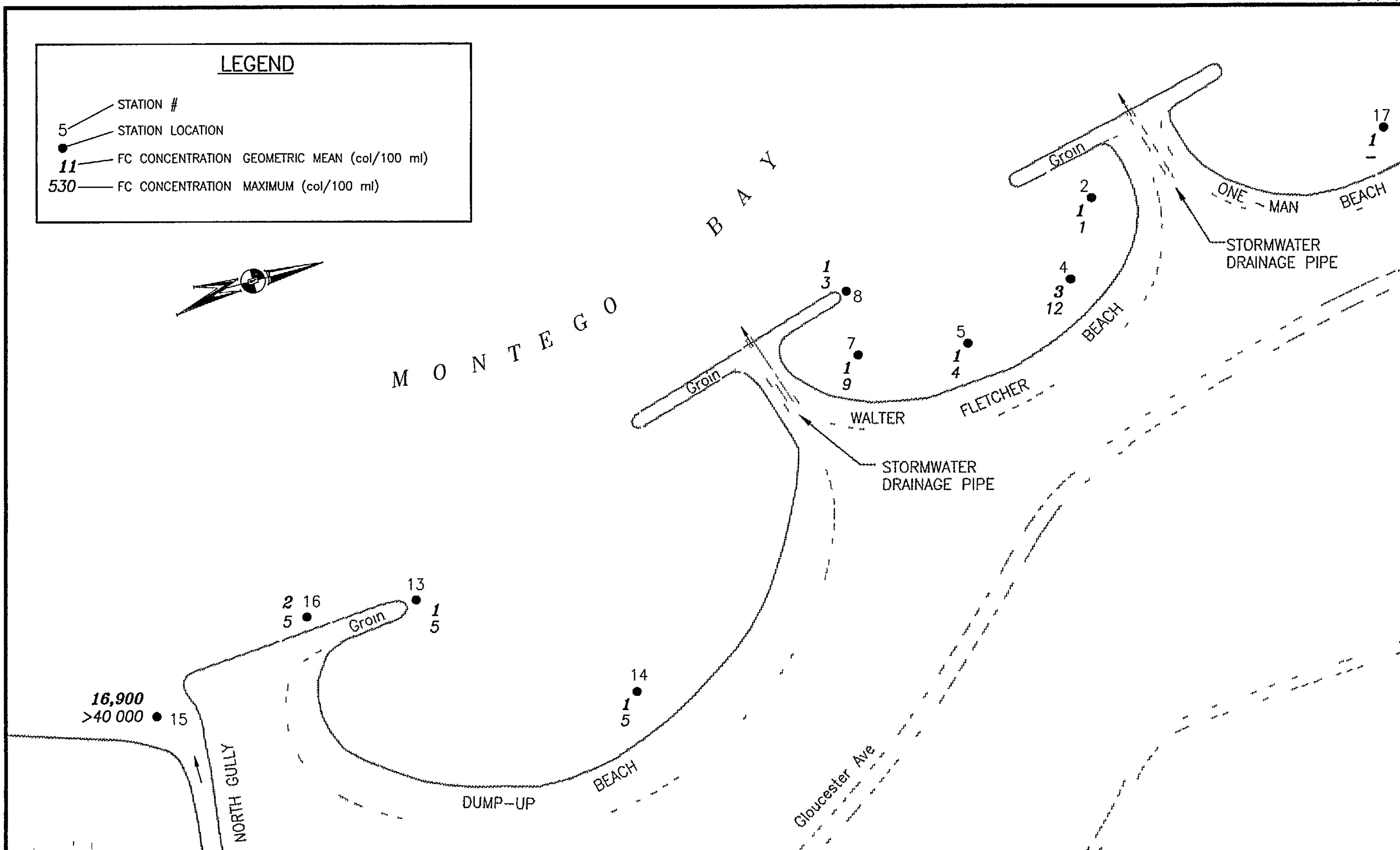


US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure B-2
LOUIS BERGER INTERNATIONAL, INC	Scale 1cm = 40 meters	MONTEGO BAY - Faecal Coliform (All Samples)
Technical Support Services, Inc	December 1997	Sampling Event 2 Sept 28 to Oct 3, 1997



US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure B-3
LOUIS BERGER INTERNATIONAL, INC Technical Support Services, Inc	Scale 1cm = 40 meters	MONTEGO BAY - Faecal Coliform (All Samples)
	December 1997	Sampling Event 3 Oct 26 to Nov 2, 1997

MBF-27 dwg 12/97\A.G



US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure B-4
LOUIS BERGER INTERNATIONAL, INC Technical Support Services, Inc	Scale 1cm = 40 meters December 1997	MONTEGO BAY - Faecal Coliform (All Samples) Sampling Event 4 Dec 7 to Dec 12, 1997

ATTACHMENT C

Faecal Coliform Concentrations and Distribution by Sampling Event:

NEGRIL

(Community Centre Beach, and Surrounding Areas)

Table C-1

Faecal Colıform Concentratıons ın Negrıl (col/100 ml)
Communıty Center Beach

SAMPLING EVENT 1 (Reconnaıssance) August 26 to 29, 1997

Location		Statıon No	Water Depth (appr m)	Sampl Tıme (h)	Thursday 28 Aug Faecal Colıform Concen-tratıon (col/100 ml) NWC Lab	Raınfall	Notes
Communıty Center Beach	450 m from mouth of S-Negrıl Rıver 30m from shore	NG- 1	1 6	7 43	**4**	Heavy raın four days prıor to sampling (Source Met Office statıon ın S-Negrıl) The dırectıon of the plume of South Negrıl Rıver movıng out to sea was WSW (ı e ıt dıd not come ashore on the Communıty Center Beach)	
	400 m from mouth of S-Negrıl Rıver 30m from shore	NG- 2	1 6	7 45	**4**		
	340 m from mouth of S-Negrıl Rıver 30m from shore	NG- 3	1 6	7 50	**20**		
	280m from mouth of S-Negrıl Rıver 30m from shore	NG- 4	1 6	7 52	**6**		
	230 m from mouth of S-Negrıl Rıver, 30m from shore	NG- 5	1 7	7 53	**40**		
	180 m from mouth of S-Negrıl Rıver 5m from shore	NG- 6	1 8	7 54	**14**		
	130 m from mouth of S-Negrıl Rıver 30m from shore	NG- 7	2 0	8 00	**8**		
South Negrıl Rıver plume	50 m northwest of northern jetty of rıver	NG- 8	>6	9 15	**70**		
	50 m west of rıver mouth	NG- 9	>6	9 20	**1,200**		(1)
South Negrıl Rıver upstream	mouth of rıver	NG- 10	2 4	9 25	**3,500**		(2 3)
	250 m from mouth at N B Blvd brıdge	NG- 11	2 0	9 30	**1,500**		(2 4)
Duplıcate	Duplıcate of Statıon NG-5	NG- 12	1 7	7 53	**50**		

NOTES

(1) The color of the sample was lıght brown
(2) The color of the sample was brownısh
(3) *In-sıtu measurements of sample* Salınıty 13 2 ppt Temperature 28 deg C Conductıvıty 14 1 uS/cm
(4) *In sıtu measurements of sample* Salınıty 1 6 ppt Temperature 27 deg C Conductıvıty 3 000 uS/cm
The salınıty at thıs statıon ıncreased below appr 50 cm due to ınflow of salıne water from the sea

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Table C 2

Faecal Colıform Concentratıons ın Negrıl (col/100 ml)

Communıty Center Beach

SAMPLING EVENT 2 28 September to 3 October 1997

Location		Statıon No	Water Depth (appr m)	Monday 29 Sep 14 45h dry Louıs Berger	Tuesday 30 Sep 13 45h dry Louıs Berger	Tuesday 30 Sep 13 45h dry NWC	Thursday 2 Oct 14 40h dry *(1)* Louıs Berger	Frıday 3 Oct 14 45h dry/wet *(2)* NWC	STATISTICS Dry weather (Sep 29 Oct 2) Berger samples: Geom Mean	Count	Minı mum	Maxı mum
North of Communıty Center Beach	1 500 m from mouth of S N Rıver (to Negrıl Gardens Hotel) 5m from shore	NG 37	0 8									
	1 250 m from mouth of S Negrıl Rıver (to Sandı San Hotel) 5m from shore	NG 36	0 8									
	1 000 m from mouth of S N Rıver (at Bar B Barn Hotel) 5m from shore	NG 34	0 8									
	750 m from mouth of S N Rıver (at Travellers Hotel) 30m from shore	NG 28										
	750 m from mouth of S N Rıver (at Travellers Hotel) 5m from shore	NG 33	0 8									
	600 m from mouth of S N Rıver (at Coral Seas Hotel) 30m from shore	NG 27										
	600 m from mouth of S N Rıver (at Coral Seas Hotel) 5m from shore	NG 32	0 8									
	450 m from mouth of S Negrıl Rıver 30m from shore	NG 1	1 6	0	0	<1	**19**	20	**2**	3	0	19
	450 m from mouth of S Negrıl Rıver 5m from shore	NG 31	0 8									
Communıty Center Beach	340 m from mouth of S Negrıl Rıver 30m from shore	NG 3	1 6	0	0	<1	**33**	25	**2**	3	0	33
	350m from mouth of S Negrıl Rıver 5m from shore	NG 30	0 8									
	230 m from mouth of S Negrıl Rıver 30m from shore	NG 5	1 7	0	0	<1	**70**	70	**3**	3	0	70
	240 m from mouth of S Negrıl Rıver 5m from shore	NG 25	0 8									
	130 m from mouth of S Negrıl Rıver 30m from shore	NG 7	2 0	0	0	<1	**150**	46	**3**	3	0	150
	140 m from mouth of S Negrıl Rıver 5m from shore	NG 29	0 8									
South Negrıl Rıver plume	50 m northwest of northern jetty of rıver	NG 8	>6	0	0	1	**270**	72	**4**	3	0	270
	50 m west of rıver mouth	NG 9	>6	**100**	**240**	823	**460**	390	**223**	3	100	460
	250 m west of rıver mouth	NG 26										
	450 m west of rıver mouth	NG 15		4	**280**	600	**290**	450	**69**	3	4	290
	800 m west of rıver mouth	NG 23										
	1 300 m west of rıver mouth	NG 24										
South Negrıl Rıver upstream	mouth of rıver	NG 10		**600**	**710**	3 000	**950**	1 775	**740**	3	600	950
	250 m from mouth at N B Blvd brıdge	NG 11		**420**	**510**	3 100	**1 600**	12 273	**700**	3	420	1 600
	900 m upstream from mouth	NG 18										
	1 500 m upstream from mouth	NG 12		**1 300**	**800**	2 927	**4 700**	18 090	**1 697**	3	800	4 700
	1 800 m upstream from mouth	NG 17						18 727			18 727	1
	2 300 m upstream from mouth	NG 19										
	2 800 m upstream from mouth	NG 13		**60**					**60**	1		
	3 200 m upstream from mouth	NG 20										
	3 800 m from mouth at NWC ponds	NG 14		**300**				8 800	**300**	1		
	4 400 m upstream from mouth	NG 21										
	4 700 m upstream from mouth	NG 22										
Duplicates	(duplicate of Statıon NG 10)	NG 10 (	2 0	**700**								
	(duplicate of Statıon NG 5)	NG 16	1 7	**0**	**0**	<1	**81**	427				

NOTES *(1)* Raın for 1 hour durıng late afternoon of prevıous day (1 8 mm) (Source Mr Johnson Meteorologıcal statıon ın Negrıl)

(2) Raın for 1 hour durıng late afternoon of prevıous day (10 mm) (Source Mr Johnson Meteorologıcal statıon ın Negrıl)

Not avaılable or not applıcable

Table C 3

Faecal Coliform Concentrations in Negril (col/100 ml)

Community Center Beach

SAMPLING EVENT 3 26 October to 2 November 1997

Location		Station No	Water Depth (appr m)	Monday 27 Oct 14 05h dry Louis Berger	Tuesday 28 Oct 14 15h dry Louis Berger	Thursday 30 Oct 14 05h dry Louis Berger	Thursday 30 Oct NWC	Sunday 2 Nov 14 45h dry/wet *(2)* NWC	STATISTICS Geom Mean	Count	Minimum	Maximum
									All samples all Berger samples & NWC samples from Nov 2			
North of Community Center Beach	1 500 m from mouth of S N River (to Negril Gardens Hotel) 5m from shore	NG 37	0 8									
	1 250 m from mouth of S Negril River (to Sandi San Hotel) 5m from shore	NG 36	0 8									
	1 000 m from mouth of S N River (at Bar B Barn Hotel) 5m from shore	NG 34	0 8			**9**			**9**	1		
	750 m from mouth of S N River (at Travellers Hotel) 30m from shore	NG 28				**0**			**0**	1		
	750 m from mouth of S N River (at Travellers Hotel) 5m from shore	NG 33	0 8			**17**			**17**	1		
	600 m from mouth of S N River (at Coral Seas Hotel) 30m from shore	NG 27				**16**			**16**	1		
	600 m from mouth of S N River (at Coral Seas Hotel) 5m from shore	NG 32	0 8			**17**			**17**	1		
	450 m from mouth of S Negril River 30m from shore	NG 1	1 6	**33**	**0**	**31**		<1	**4**	4	0	33
	450 m from mouth of S Negril River 5m from shore	NG 31	0 8			**10**			**10**	1		
Community Center Beach	340 m from mouth of S Negril River 30m from shore	NG 3	1 6	**37**	**0**	**28**		<1	**4**	4	0	37
	350m from mouth of S Negril River 5m from shore	NG 30	0 8			**13**			**13**	1		
	230 m from mouth of S Negril River 30m from shore	NG 5	1 7	**41**	**0**	**25**	32	<1	**4**	4	0	41
	240 m from mouth of S Negril River 5m from shore	NG 25	0 8	**10**		**60**			**24**	2	10	60
	130 m from mouth of S Negril River 30m from shore	NG 7	2 0	**31**	**0**	**51**		<1	**4**	4	0	51
	140 m from mouth of S Negril River 5m from shore	NG 29	0 8			**15**			**15**	1		
South Negril River plume	50 m northwest of northern jetty of river	NG 8	>6	**87**	**0**	**92**		<1	**7**	4	0	92
	50 m west of river mouth	NG 9	>6	***120***	***81***	***350***		380	***190***	4	*81*	380
	250 m west of river mouth	NG 26			**29**	**0**		18	**6**	3	0	29
	450 m west of river mouth	NG 15		**<10**	**140**	**0**	<1	<1	**4**	4	0	140
	800 m west of river mouth	NG 23		**<10**	**2**	**0**	<1	2	**2**	4	0	5
	1 300 m west of river mouth	NG 24		**<10**	***0***	**0**		<1	**1**	4	0	5
South Negril River upstream	mouth of river	NG 10		**34**	**50**	**1 080**		1 423	**226**	4	34	1 423
	250 m from mouth at N B Blvd bridge	NG 11		**119**	**260**	**>6 000**	4 000	1 009	**658**	4	119	>6 000
	900 m upstream from mouth	NG 18		**140**	**<10**	**80**		320	**65**	4	5	320
	1 500 m upstream from mouth	NG 12		**15**	**1**	**110**		2 900	**47**	4	1	2 900
	1 800 m upstream from mouth	NG 17		**190**	**10**	**81**	160	144	**69**	4	10	190
	2 300 m upstream from mouth	NG 19		**230**		**60**		99	**111**	3	60	230
	2 800 m upstream from mouth	NG 13		**12**		**54**		210	**51**	3	12	210
	3 200 m upstream from mouth	NG 20		**50**		**30**		153	**61**	3	30	153
	3 800 m from mouth at NWC ponds	NG 14		**220**		**210**		210	**213**	3	210	220
	4 400 m upstream from mouth	NG 21		**190**		**530**		520	**374**	3	190	530
	4 700 m upstream from mouth	NG 22		**250**		**530**		350	**359**	3	250	530
Duplicates	Duplicate *(1 2)*	NG 16		**48**	**0**	**16**	30	*(2)*				

OTES *(1)* Duplicate stations *10/27 10/28 and 10/30* NG 5 11/2 see Note (2) below

(2) Four duplicates on this day NG 16 (=NG 5) *<1 MPN/100 ml* NG 135 (=NG 18) *570 MPN/100 ml* NG 136 (=NG 10) *1 180 MPN/100 ml* NG 137 (NG 26) *9 MPN/100 ml*

(3) Rain fell on the day before (1 Nov 97) around 16 00h within the watershed of the South Negril River Estimated rain volume 5 to 10 mm

Rainfall occurred during incoming tide (high tide was estimated with 22 00h) Sampling on 2 Nov 97 occurred during the second outgoing tide after rainstorm

Not available or not applicable

FC OCT97 XLS 1/7/98 9 29 PM

Table C 4

Faecal Coliform Concentrations in Negril (col/100 ml)

Community Center Beach

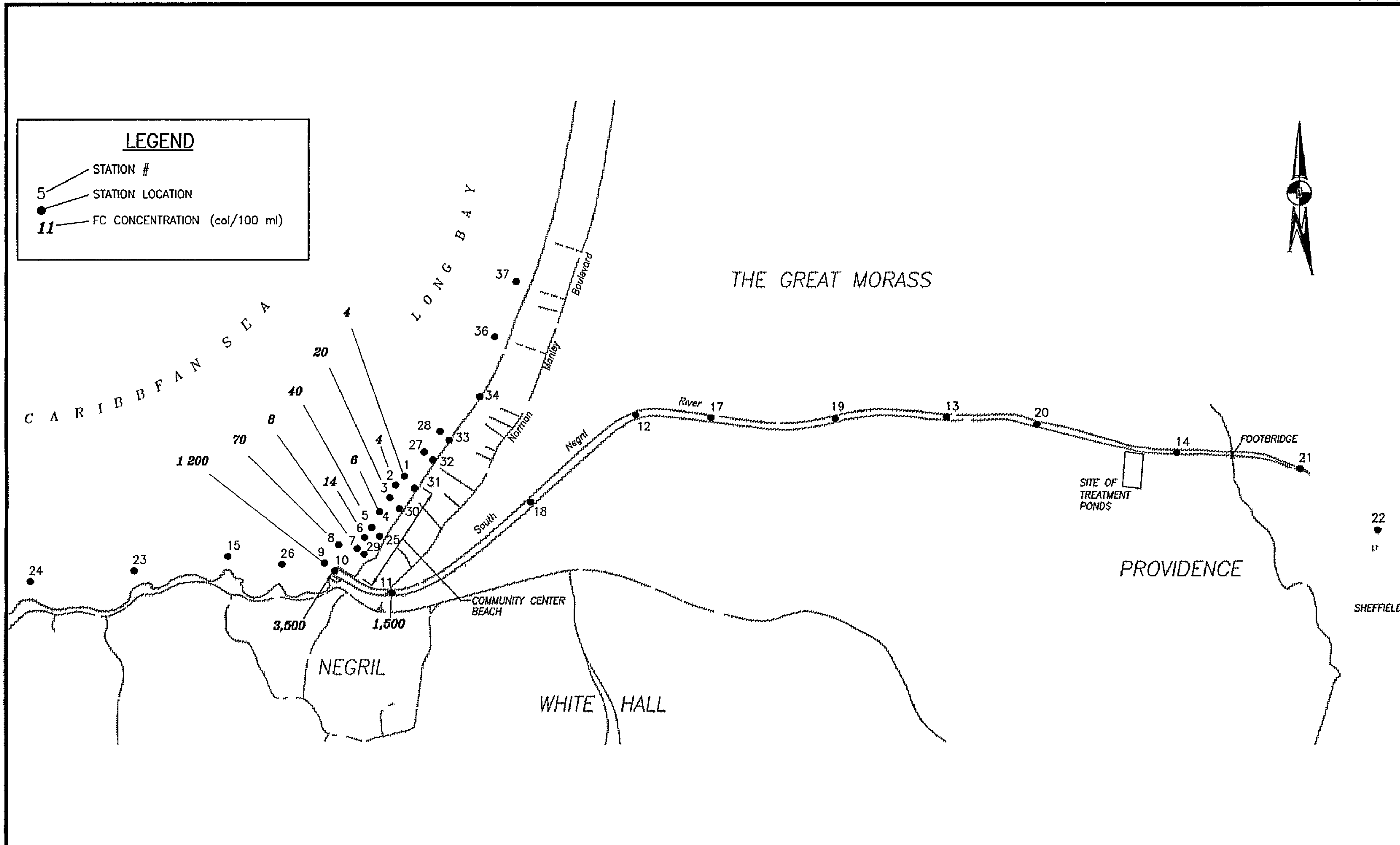
SAMPLING EVENT 4 December 7 to 12 1997

Location		Station No	Water Depth (appr m)	Monday 8 Dec 13 30h dry Louis Berger	Monday NWC	Tuesday 9 Dec 12 50h dry Louis Berger	Tuesday NWC	Wednesday 10 Dec 9 15h dry Louis Berger	Wednesday NWC (MF)	Wednesday NWC (MT)	Wednesday NRCA	Thursday 11 Dec 13 15h dry Louis Berger	Thursday NWC	STATISTICS All samples Geom Mean	Count	Minimum	Maximum
														all Berger samples			
North of Community Center Beach	1 500 m from mouth of S N River (to Negril Gardens Hotel) 5m from shore	NG 37	0 8	60		0								5	2	0	60
	1 250 m from mouth of S Negril River (to Sandi San Hotel) 5m from shore	NG 36	0 8	11		0								2	2	0	11
	1 000 m from mouth of S N River (at Bar B Barn Hotel) 5m from shore	NG 34	0 8	26		6								12	2	6	26
	750 m from mouth of S N River (at Travellers Hotel) 30m from shore	NG 28		43		40		0						9	3	0	43
	750 m from mouth of S N River (at Travellers Hotel) 5m from shore	NG 33	0 8	80										80	1		
	600 m from mouth of S N River (at Coral Seas Hotel) 30m from shore	NG 27															
	600 m from mouth of S N River (at Coral Seas Hotel) 5m from shore	NG 32	0 8														
	450 m from mouth of S Negril River 30m from shore	NG 1	1 6	3 130		53		2				0		20	4	0	3 130
	450 m from mouth of S Negril River 5m from shore	NG 31	0 8														
Community Center Beach	340 m from mouth of S Negril River 30m from shore	NG 3	1 6	60		230		0				0	<1	8	4	0	230
	350m from mouth of S Negril River 5m from shore	NG 30	0 8														
	230 m from mouth of S Negril River 30m from shore	NG 5	1 7	200	298	330	ed	0	ed		<2	0		11	4	0	330
	240 m from mouth of S Negril River 5m from shore	NG 25	0 8	76										76	1		
	130 m from mouth of S Negril River 30m from shore	NG 7	2 0	130		350		0				0		10	4	0	350
	140 m from mouth of S Negril River 5m from shore	NG 29	0 8														
South Negril River plume	50 m northwest of northern jetty of river	NG 8	>6	12	40	510	ed	0				130		25	4	0	510
	50 m west of river mouth	NG 9	>6	13		510		1 100	ed	3 500	>1 600	400	1 200	232	4	13	1 100
	250 m west of river mouth	NG 26		1		170		280				114	106	48	4	1	280
	450 m west of river mouth	NG 15		3	10	4		4				20		6	4	3	20
	800 m west of river mouth	NG 23		2		1		0				0		1	4	0	2
	1 300 m west of river mouth	NG 24		2		0		0				0		1	4	0	2
South Negril River upstream	mouth of river	NG 10		<10		840		760	ed	1 600	1 100	980		236	4	5	980
	250 m from mouth at N B Blvd bridge	NG 11		1 900	4 500	1 200	ed	820	ed	1 700	340	440	1 613	952	4	440	1 900
	900 m upstream from mouth	NG 18		580		190		76				113		175	4	76	580
	1 500 m upstream from mouth	NG 12		80		810		170				132		195	4	80	810
	1 800 m upstream from mouth	NG 17		240	500	1 420		200	ed		300	130	207	307	4	130	1 420
	2 300 m upstream from mouth	NG 19		140		670	ed	290				390		321	4	140	670
	2 800 m upstream from mouth	NG 13		120		260		200				500		236	4	120	500
	3 200 m upstream from mouth	NG 20		93		290		190				470		222	4	93	470
	3 800 m from mouth at NWC ponds	NG 14		260		510		690				610		486	4	260	690
	4 400 m upstream from mouth	NG 21				180		125				140		147	3	125	180
	4 700 m upstream from mouth	NG 22															
Duplicates	Duplicate *(1)*	NG 16		25		370	ed	0	ed		2	230					
	Duplicate of NG 9	NG 9a							ed		>1 600						

OTES *(1)* Duplicate stations 12/8 NG 28 12/9 NG 5 12/10 NG 5 12/11 NG 17

ed Edited due to analytical quality control problems

Not available or not applicable



NGF-39 dwg 12/97\AG

US AGENCY FOR INTERNATIONAL DEVELOPMENT

LOUIS BERGER INTERNATIONAL, INC

Technical Support Services, Inc

COASTAL WATER QUALITY MONITORING

Scale 1cm = 200 meters

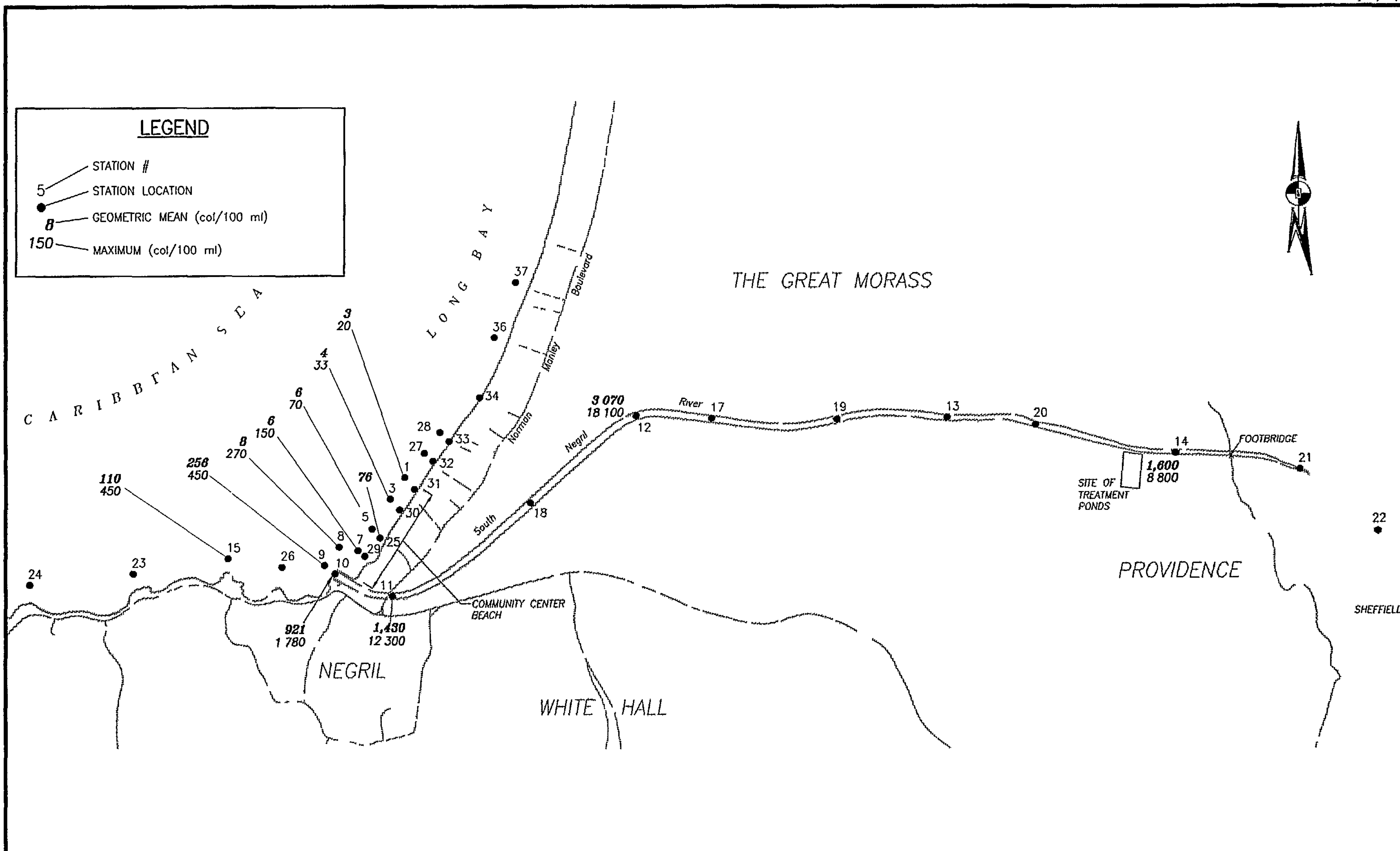
December 1997

Figure C-1

NEGRIL - Faecal Coliform (All Samples)

Sampling Event 1 (Reconnaissance) Aug 28, 1997

NCF-34 dwg 12/97\A.C



US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure C-2
LOUIS BERGER INTERNATIONAL, INC Technical Support Services, Inc	Scale 1cm = 200 meters	**NEGRIL - Faecal Coliform (All Samples)** Sampling Event 2 Sept 28 to Oct 3, 1997)
	December 1997	

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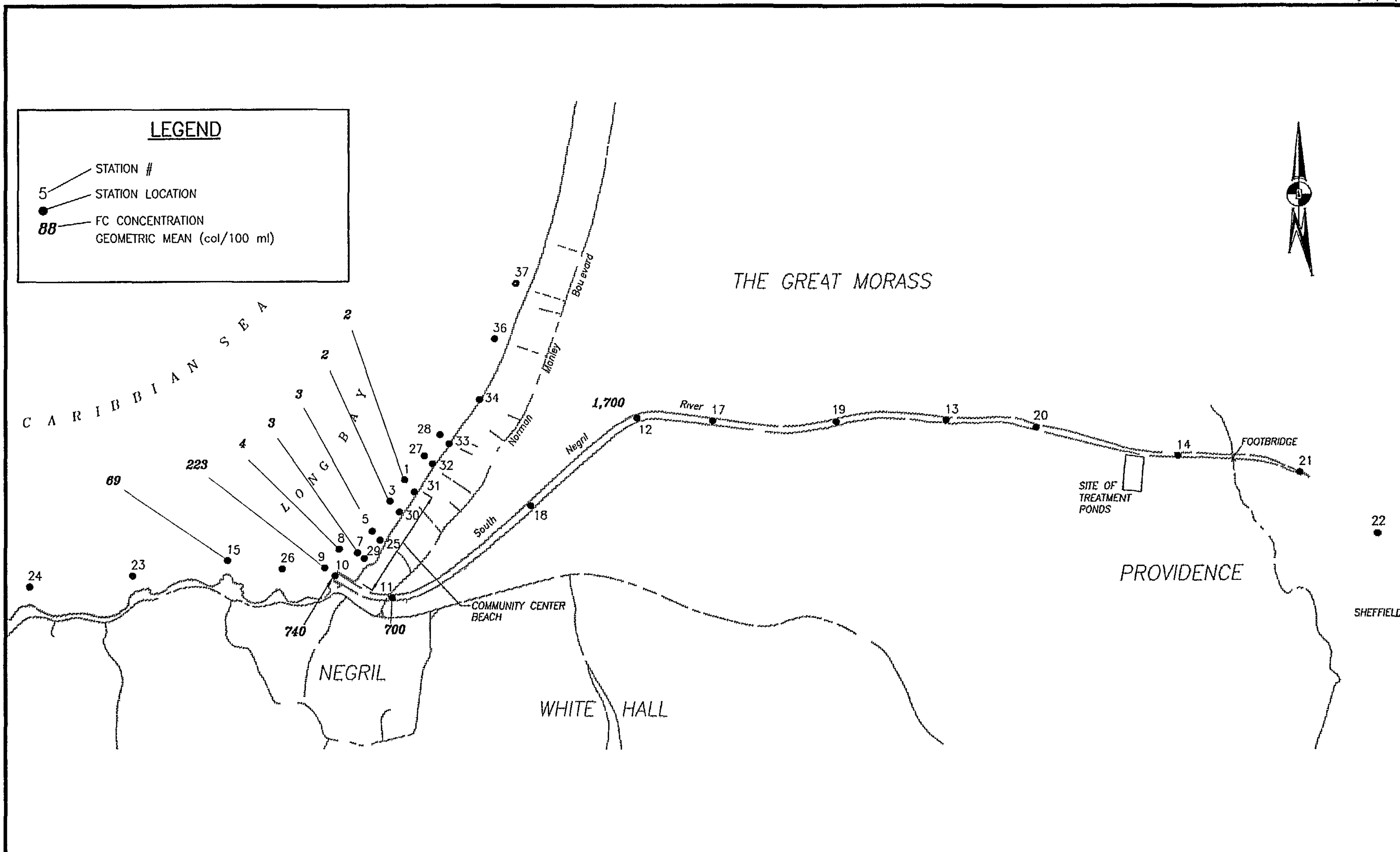
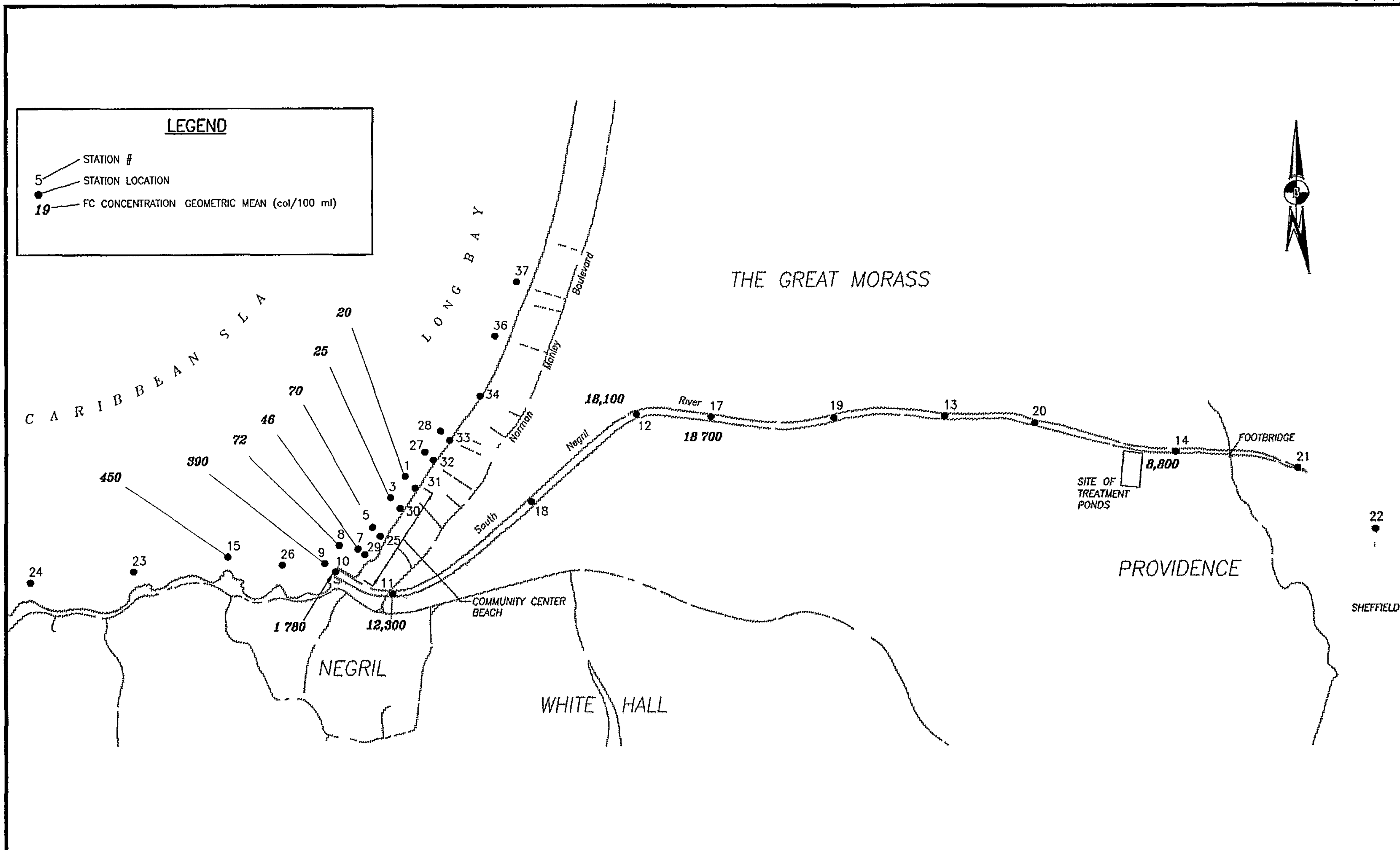
NGF-35 dwg 12/97\A.G



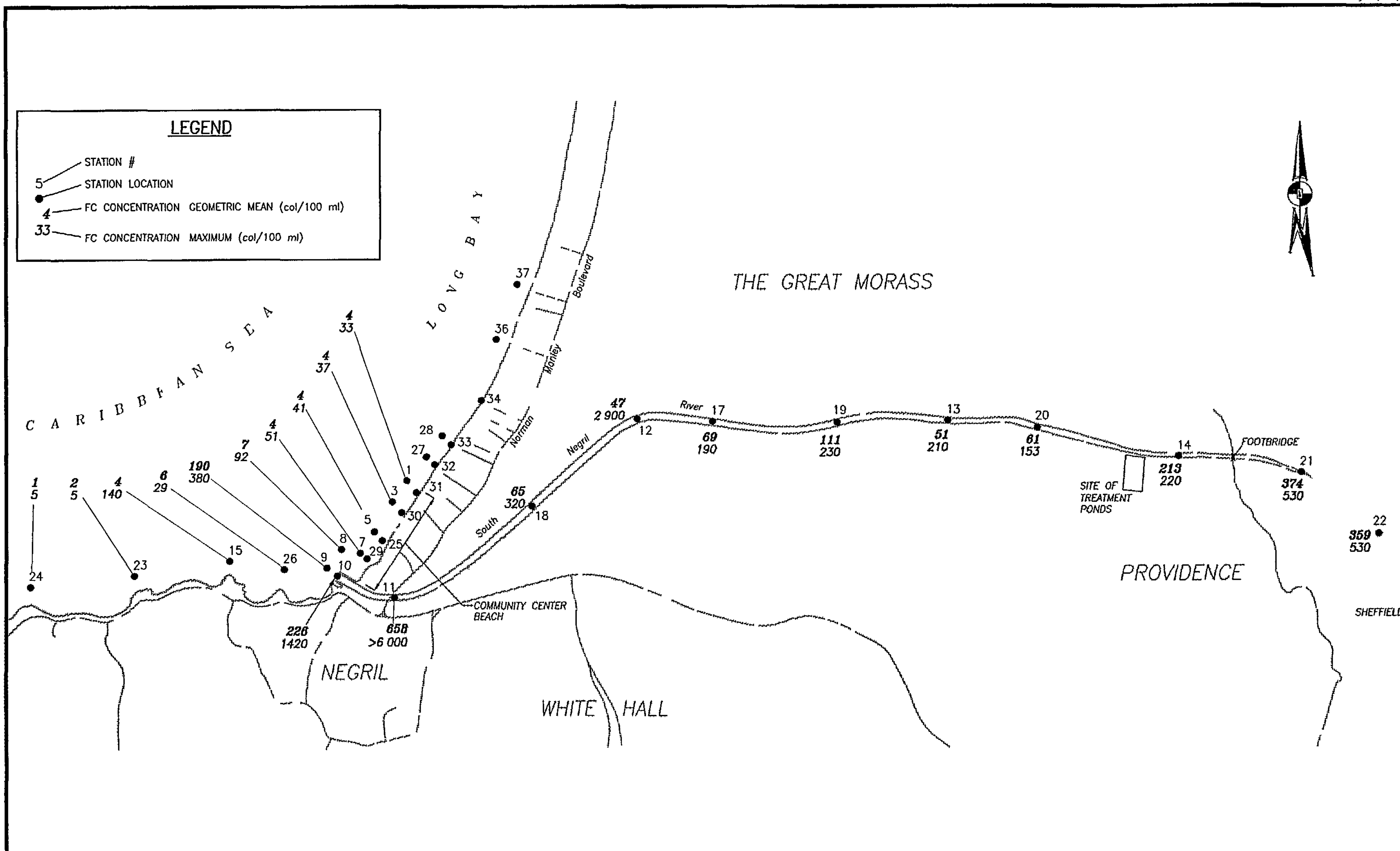
US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure C-2a
LOUIS BERGER INTERNATIONAL, INC	Scale 1cm = 200 meters	**NEGRIL - Faecal Coliform (Dry Weather)**
Technical Support Services, Inc	December 1997	Sampling Event 2 Sept 28 to Oct 3, 1997)

NGF-36 dwg 12/97\A.C



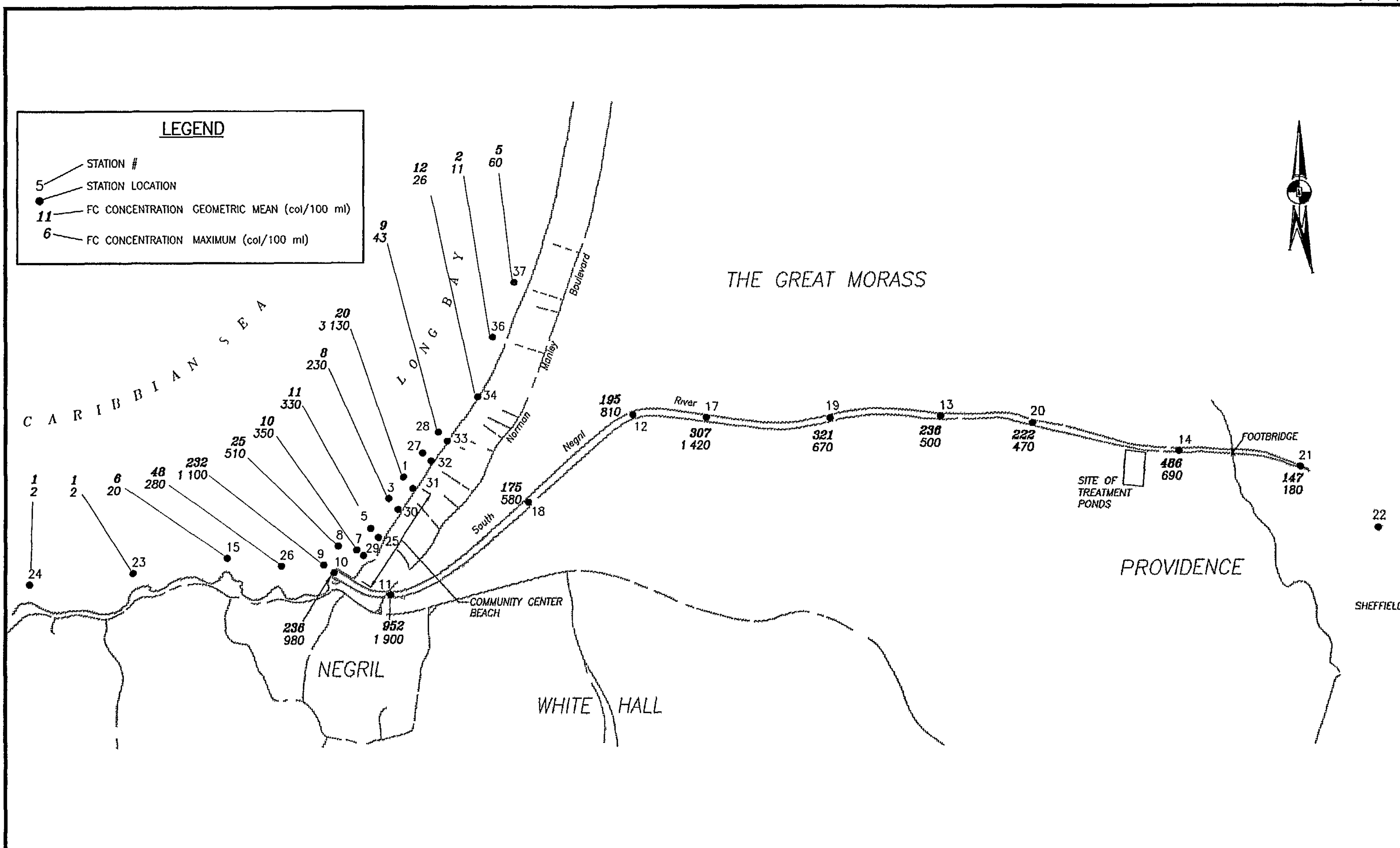
US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure C-2b
LOUIS BERGER INTERNATIONAL, INC Technical Support Services, Inc	Scale 1cm = 200 meters December 1997	**NEGRIL - Faecal Coliform (Wet/Dry)** Samples One Day after Rain on Oct 2, Sampling Event 2 Sept 28 to Oct 3, 1997

NGF-37 dwg 12/97\A.G



US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure C-3
LOUIS BERGER INTERNATIONAL, INC Technical Support Services, Inc	Scale 1cm = 200 meters	NEGRIL - Faecal Coliform (All Samples)
	December 1997	Sampling Event 3 Oct 26 to Nov 2, 1997

NGF-38 dwg 12/97\A.C



US AGENCY FOR INTERNATIONAL DEVELOPMENT	COASTAL WATER QUALITY MONITORING	Figure C-4
LOUIS BERGER INTERNATIONAL, INC	Scale 1cm = 200 meters	NEGRIL - Faecal Coliform (All Samples)
Technical Support Services, Inc	December 1997	Sampling Event 4 Dec 7 to Dec 12, 1997

ATTACHMENT D

Quality Control Information

(Sampling Events 1 to 4)

Attachment D
Quality Control Evaluation of Field Laboratory

1. Overview of QA/QC

The purpose of a quality assurance (QA) and quality control (QC) procedures is to ensure that the assay results are both accurate and reproducible by other laboratories conducting the same assays Given the importance of the results from the Jamaica Faecal Coliform Project to both public health and environmental managers in Jamaica, a particularly high level of QA/QC approaches were designed into the programme In addition, strict adherence to accepted methodological protocols were maintained An important aspect of the present programme was the adherence to the <6 hour holding time for the water samples During the course of the study more than 90% of the samples were transported to the laboratory within 6 hours of collection for processing within 2 hours, no sample was used after a holding time of longer than 8 hours

2 QA/QC approaches for Berger field laboratory

The Berger field laboratory used five mechanisms for ensuring data quality (1) >5% of the samples were blind field duplicates, (2) confirmation of identified faecal coliforms and non-faecal coliforms were performed using the gas production technique to ensure that colonies identified as faecal coliforms were not other heterotrophic (non-faecal coliform) bacteria, (3) sterile blanks were assayed with every sample series with occasional blind field sterile blanks, (4) a comparison of buffer used in the Berger field laboratory and buffer prepared by a USEPA certified public health laboratory was conducted, and (5) laboratory intercalibrations were run with three laboratories in Jamaica, a USEPA certified laboratory in the United States (Barnstable County Health Department) which routinely performs faecal coliform analyses

QA/QC samples were collected from all of the beaches monitored, both Turtle and Sailor Hole Beaches in Ocho Rios, Walter Fletcher and Dump-up Beaches in Montego Bay and Community Centre Beach in Negril The sampling was daily, although not at all sites and ran from September 28 through October 3, 1997, October 26 through 31, 1997 and December 7 through 12, 1997 The breakdown of QA samples is detailed in Table D-1

An additional analytical procedure was to perform all assays with multiple dilutions (from 2-4/sample) in order to keep the counts per filter to less than 60 and almost always to less than 100 Additional dilutions were performed during rain event sampling in order to keep the counts to within methodologically proscribed levels If the number of colonies per filter becomes too high, not only are the plates difficult to count, but the colonies can begin to compete for resources causing misleading results

The incubator temperatures were also routinely monitored as incubation temperature is critical to the precision of the method Temperature control on the incubators was always within the ± 0.2°C required by the method

Table D-1
Internal QA/QC Procedures and Results over the 1997 Sampling Period

Laboratory	Field Samples	Intra-Lab[1] QA-Duplicates	Intra-Lab[2] Dilution-Duplicates	Blanks[3] +/total	Confirmation Tests[4]
Berger Field Lab	845	55 (6%)	237 (26%)	0/39	149 (+) 93% (-) 85%

(1) These are blind duplicate field samples
(2) These are sample splits which gave readable plates at 2 dilutions
(3) Number of blanks showing counts (+) per total conducted
(4) Number of confirmation tests by gas formation %'s indicate correct + and - confirmations

3 Field Laboratory QA/QC Evaluation

The laboratory operated throughout the Water Quality Project at a high level This was due to the strict adherence to methodologies, the compliance with the 6 hour holding time for field samples, the single focus on microbial analysis (a full laboratory generally has a diversity of chemical and biological assays being performed simultaneously), the high degree of QA/QC checks, and the use of state-of-the-art techniques

One of the major roles of the QA programme is to ensure that the levels of faecal coliforms reported are not artificially too high or too low This was accomplished by assaying sterile controls, which would yield values incorrectly high and through tests which confirm that identification of faecal coliform (positive) and non-faecal coliform (negative) colonies are correct In these confirmation tests, false positives result in too high counts and false negatives too low counts

Sterile control samples were run with each batch of samples assayed and always showed no growth, even field blanks which were transported through the field sampling These sterile control samples added 4% more samples, but were critical as they provided an important check on contamination From the assay of the control samples and the fact that various sampling locations at each beach showed no faecal coliforms, it is certain that contamination was not a problem in this study

Confirmation tests of both positive and negative faecal coliform identifications were conducted to maintain identifications These tests are needed to ensure that the visual identification (using a microscope and fluorescent light) of colonies on the incubated membrane filters are being properly classified as faecal and non-faecal coliforms About half of the total tests were performed during the initial sampling to develop the site-specific visual characteristics of faecal coliform colonies Periodic confirmations were performed during each of the sampling events The confirmation procedure primarily targeted colonies which suggested some uncertainty in actual field samples from each of the study sites Individual colonies which were identified as faecal coliform and non-faecal coliform in routine counting were transferred from the incubated filters to a liquid lauryl tryptose media and incubated for 24 hours at 35°C If this incubation generates gas, then a second transfer to EC broth is performed for 24 hour incubation at 44 5°C Generation of gas in this final incubation confirms faecal coliform, failure to generate gas confirms non-faecal coliform The 149 confirmation tests conducted were about equally divided between visually identified faecal and non-faecal coliforms Of the total tests conducted, 93% of the colonies deemed to be faecal coliform and 85% of the non-faecal colonies were correctly identified (Table 1) This indicates a high degree of accuracy in identification since (1) obvious identifications were rarely checked almost all of the effort was in verifying the difficult- to-identify colonies, and (2) almost all of the colonies on a filter were faecal coliform, so the larger percent error in the non-faecal identifications actually represents a small error in the actual counts

One other factor which can influence the accuracy of the assay is the quality of the buffer solution used to make up the sample dilutions Although fresh buffer was made for each sampling day and the water used was rated as Type II quality, a buffer check was performed To check the quality of the buffer used in this study, a comparison of results from diluted field samples run using the on-site buffer versus buffer made up by a USEPA certified microbiological laboratory was conducted The U S laboratory routinely has its water certified for microbiological use Field samples requiring dilution and assayed using both buffers showed good agreement in faecal coliform counts indicating that the buffer produced on-site was of high quality (Figure D-1)

The use of blind field duplicates provides the best approach for determining the repeatability and precision of the overall coliform monitoring programme Field duplicates are samples collected separately at a field site at the same time but with a separate identification number The location of the duplicates was not known to laboratory personnel until after data processing From these samples an estimate of the combined sampling and analytical errors can be determined which is more robust than the typical approach of running duplicate assays from the same bottle on a small percentage of the samples For the 900 samples analyzed for faecal coliforms, an additional 55 blind duplicates were assayed for an increase of 6% in total analyses

The results of these blind duplicate QA samples indicate a high degree of precision (Figures D-2 to D-4) Of the 54 pairs of samples (one sample from Trip 4 was not included for QA reasons) the average difference was about 10% Data was assayed both untransformed and $\log_{10}$ transformed The precision of the assay is further assessed from the linear regression of the duplicates from all of the sampling events The data was clearly directly related (slope=1 02) and showed little difference between paired samples (r^2=0 98) Note that a similar analysis of the 15 blind samples duplicates assayed by the NWC laboratory in Bogue showed only slightly more variable results However, given the lower number of duplicates the linear regression coefficient showed excellent replication (r^2=0 87 with a slope of 1 06) The two other laboratories in Jamaica had insufficient field duplicates to evaluate precision All of these analyses support the conclusion that the data were highly reproducible and that the method showed little variability in the assay of natural samples by the same laboratory

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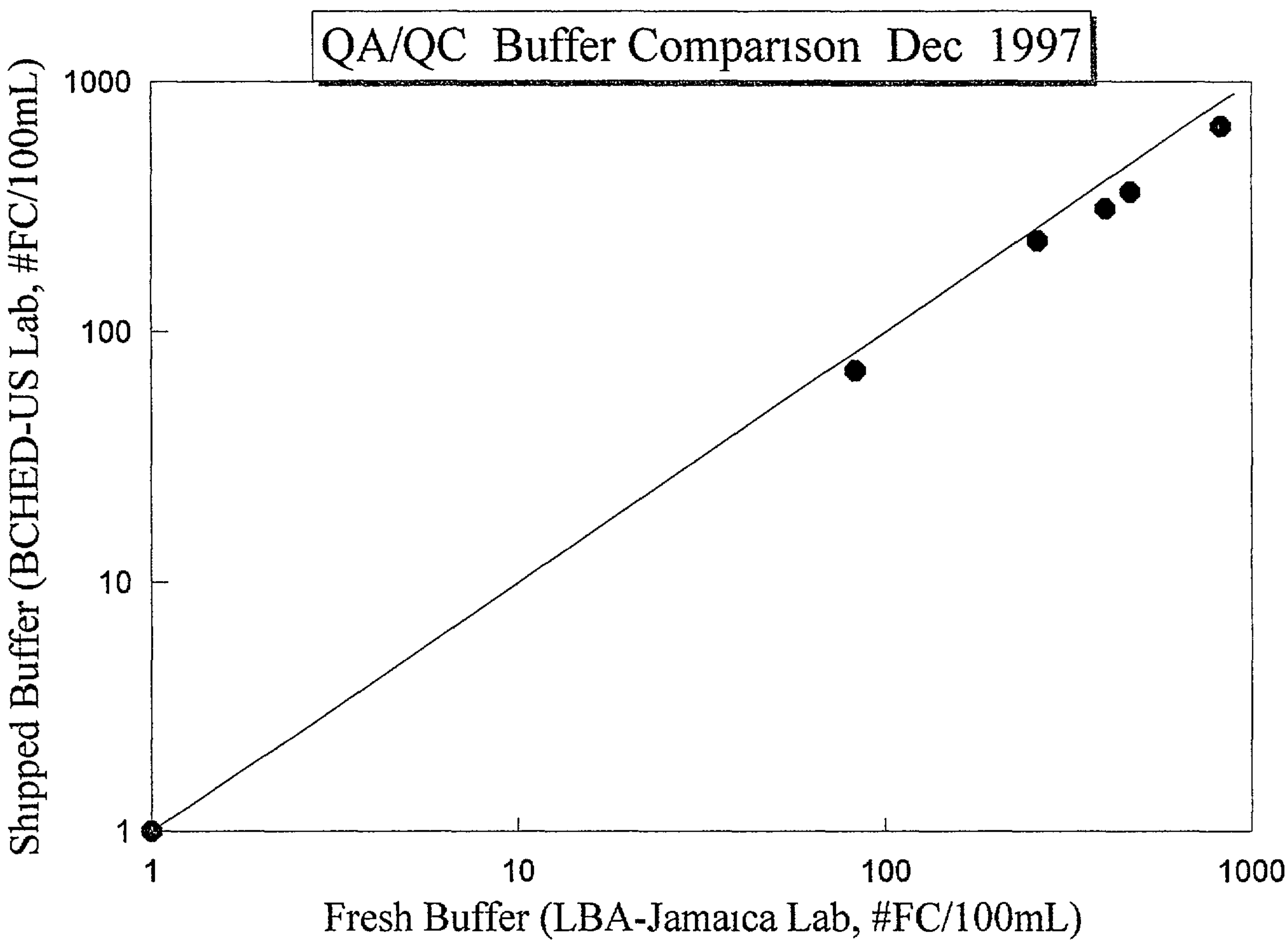
Another evaluation of the performance of the assay is to examine assays of the same sample (from the same bottle) but analyzed at different dilutions Only samples can be used where there are sufficient faecal coliforms to give results for the higher dilution but not so many that the lower dilution has so many colonies that it cannot be counted Of the 900 field samples analyzed by the Berger field laboratory, 237 had adequate data from the 100 ml and 10 ml assays for comparison (Figure D-5) While the data show some variation overall there is excellent agreement between the dilutions Linear regression analysis yields a slope of 0 96 compared to 1 00 for a perfect fit and an r^2=0 89 The r^2 is a measure of the variation between the dilutions These results not only indicate that the dilutions were being performed properly, but also that there was no inhibition or stimulation of faecal coliform recovery when buffer (10 ml assays) versus no buffer (100 ml assays) was used Taken together the blind duplicates and the dilution comparisons indicate a high degree of precision in the faecal coliform assay as performed in this study

Figure D-1



LBA Lab = [US Lab x 1 27] - 5, R2=0 997, N=6

Figure D-2

Comparison of Duplicate Samples
Berger Field Laboratory - Internal Duplicates

SAMPLING EVENT 2 28 September to 3 October 1997

Louis Berger	Ocho Rios Original	Ocho Rios Duplicate	Montego Bay Original	Montego Bay Duplicate	Negril Original	Negril Duplicate
28 Sep pm	0	0				
29 Sep am	160	270	1	0	600	700
pm	0	0			0	0
30 Sep am	33	34	0	0		
pm	1	0			0	0
1-Oct am	67	74				
mid						
pm	19	17				
2 Oct am	37	50	0	0		
pm	34	37			70	81
pm(late)	170	170				
3 Oct am	20	50				
pm						

NWC	Ocho Rios Original	Ocho Rios Duplicate	Montego Bay Original	Montego Bay Duplicate	Negril Original	Negril Duplicate
28 Sep pm						
29 Sep am	616	504				
pm						
30 Sep am			1	<1		
pm					<1	<1
1-Oct am						
mid						
pm						
2-Oct am	125	108				
pm						
pm(late)						
3 Oct am			2	7		
pm					70	427

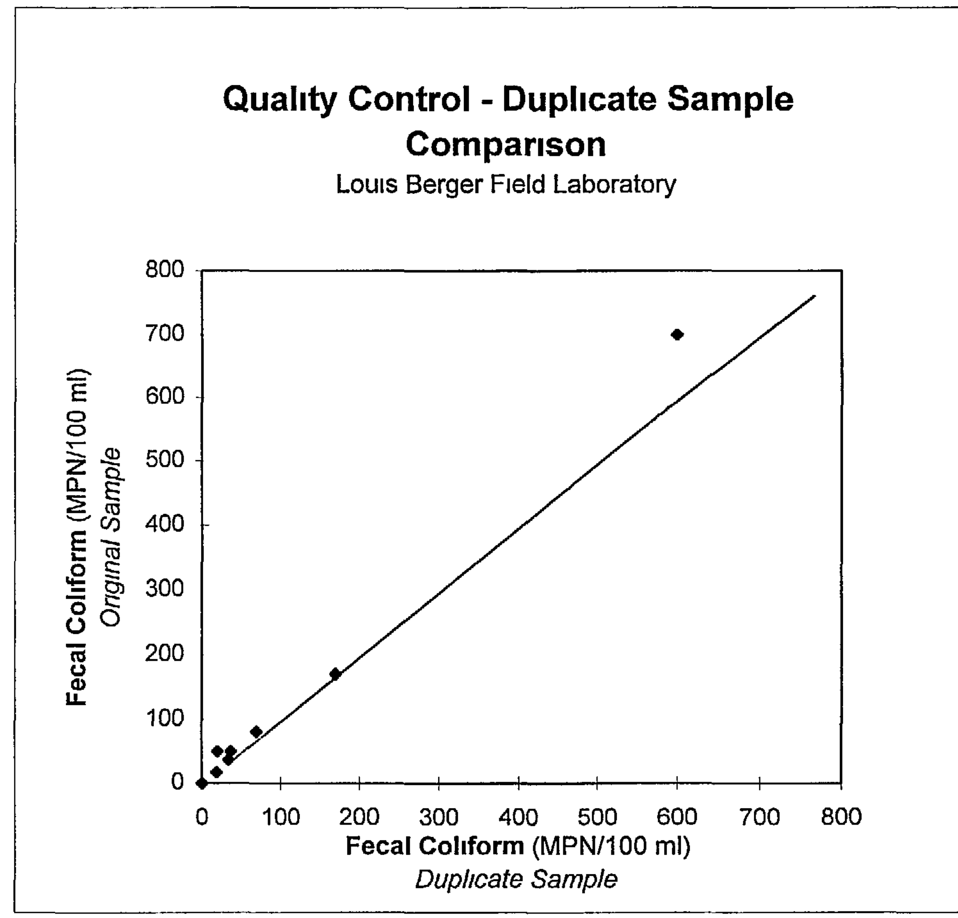


Figure D-3

Comparison of Duplicate Samples
Berger Field Laboratory - Internal Duplicates
SAMPLING EVENT 3 26 October to 2-November 1997

Louis Berger	Ocho Rios Original	Ocho Rios Duplicate	Montego Bay Original	Montego Bay Duplicate	Negril Original	Negril Duplicate
26 Oct pm	320	60	3	1		
27 Oct am	3	1	*6 000*	*6 000*		
pm	5	8			41	48
28 Oct am	51	64	47	52		
pm	3	1			*0*	*0*
29 Oct am	31	56				
pm	60	28	*0*	1		
30 Oct am	130	117				
pm	1 900	1 020	*0*	*0*	25	16
31 Oct am	142	150				
mid day			10	2		
2 Nov am						

NWC	Ocho Rios Original	Ocho Rios Duplicate	Montego Bay Original	Montego Bay Duplicate	Negril Original	Negril Duplicate
26 Oct pm						
27 Oct am						
pm						
28 Oct am						
pm						
29 Oct am	30	27				
pm						
30 Oct am	270	250			32	30
pm						
31 Oct am						
mid day	104	208	10	2		
2 Nov am					*1*	*1*
					320	570
					1 423	1 180
					18	9

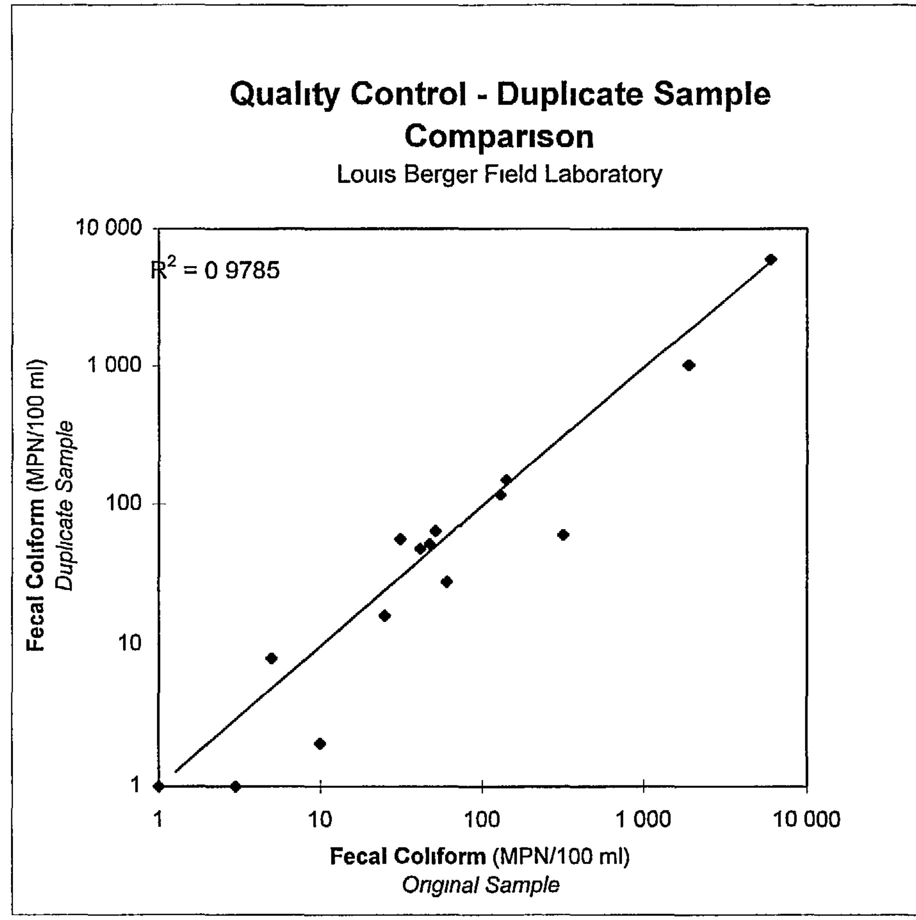


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Figure D-4

Comparison of Duplicate Samples
Berger Field Laboratory - Internal Duplicates

SAMPLING EVENT 4 December 7 to 12 1997

Louis Berger	Ocho Rios		Montego Bay		Negril	
	Original	Duplicate	Original	Duplicate	Original	Duplicate
7 Dec noon	77	17	9	6		
8 Dec am	45	24				
pm	6 400	500	5	0	43	25
9 Dec am	280	15				
pm	0	1	0	1	330	370
10 Dec	230	50	2	0	0	0
			1	0		
11 Dec	66	89	1	1	130	230
12 Dec	72	63				

NWC	Ocho Rios		Montego Bay		Negril	
	Original	Duplicate	Original	Duplicate	Original	Duplicate
7 Dec noon						
8 Dec am						
pm						
9 Dec am						
pm						
10 Dec						
11 Dec						
12 Dec						

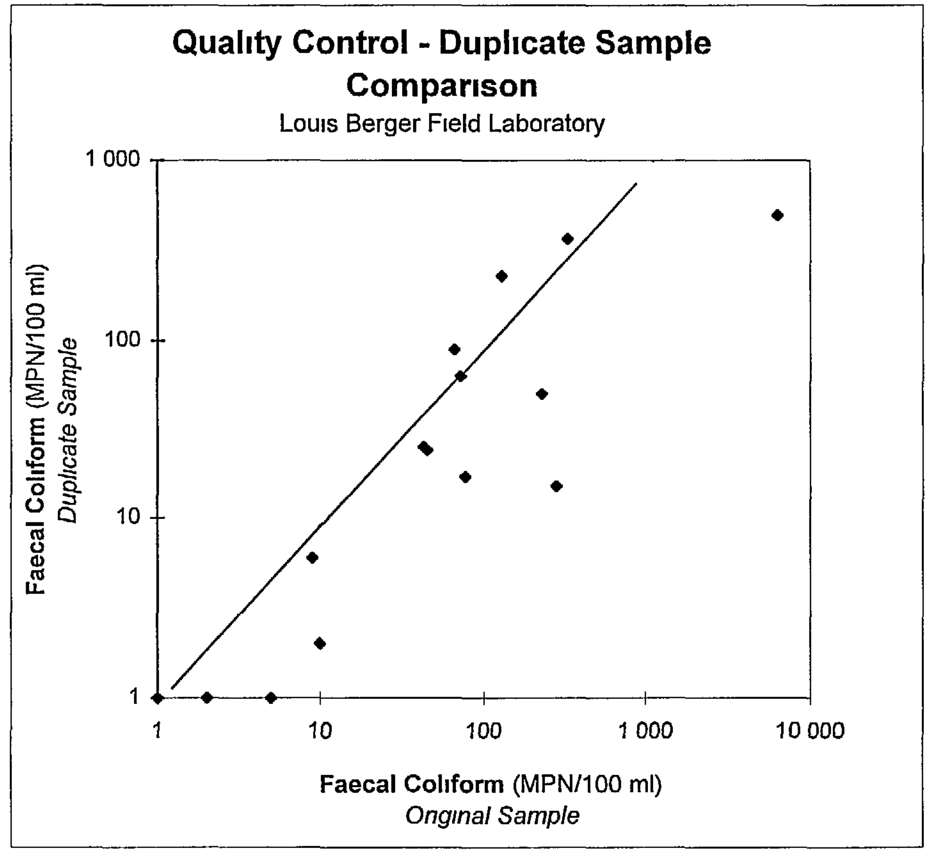
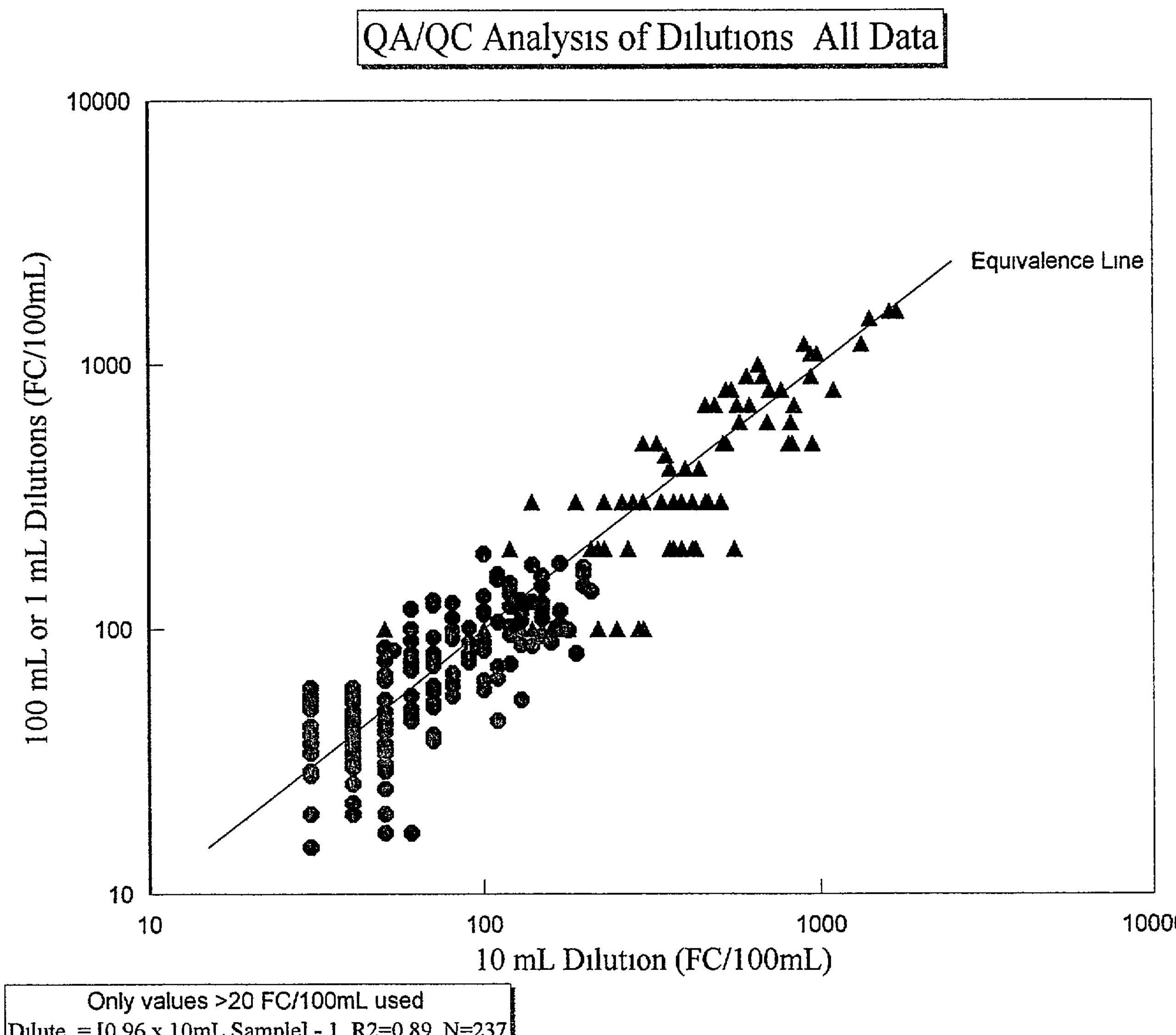


Figure D-5



QA/QC Analysis of Dilutions All Data
10000
1000
100
10
100 mL or 1 mL Dilutions (FC/100mL)
Equivalence Line
10
100
1000
10000
10 mL Dilution (FC/100mL)
Only values >20 FC/100mL used
Dilute = [0 96 x 10mL Sample] - 1, R2=0 89 N=237

ATTACHMENT E

Laboratory Intercalibration

(Sampling Events 2 to 4)

Attachment E
Laboratory Intercalibration of Faecal Coliform Determination

1 Overview

In order to begin development of a proficiency procedure for faecal coliform testing of Jamaican waters, parallel samples were assayed in the Berger field laboratory and 3 laboratories in Jamaica The goal of this preliminary effort was to determine the comparability of data assayed by different water quality laboratories Samples for this intercalibration were collected simultaneously and transported to participating laboratories for analysis generally within proscribed holding time of 6 hours, but always within 10 hour of collection (up to 24 hours can be acceptable under proper transport conditions) Control samples were also assayed and all sampling sites were coded following proficiency protocols Given relatively short sample holding times specified by the method (<6 hours), most of the intercalibration data from this major sampling series was from the NWC's Bogue Lab for logistical reasons

2 Results

Given the logistical considerations, the largest number of calibration samples were performed with the Berger field laboratory and the NWC laboratory (130 samples in total) (Tables E-1 to E-3) Comparison of these data indicate a good agreement between these laboratories which both use the membrane filtration technique (r^2 of linear regression is 0 92, Figures E-1 to E-3) These data were evaluated to determine the level of agreement between the laboratories and the degree of variability Comparison of data from all surveys shows about a 10% average difference in faecal coliform levels reported by each laboratory for the same samples This difference is similar to that for duplicate samples conducted by the same laboratory (Attachment D) The tendency was for the NWC results to be slightly higher than the Berger results (regression slope=1 09) However, a paired t-test (N=130) indicated that there was no significant difference between the faecal coliform results from these two laboratories (p=0 60) The large number of samples collected over several months and the high degree of comparability between the laboratories' results support the inclusion of the non-duplicate samples collected during this study and assayed by the NWC laboratory into our overall water quality data base This combined data set forms the basis for the water quality evaluations performed in the present study

The other two laboratories had only limited inter-calibration samples (NRCA=34, Kolbusch=20), more are needed before any reasonable evaluation can be performed However, it did appear from these preliminary data that these two laboratories sometimes yield higher counts than either the Berger or NWC laboratories Although after some procedural modifications were put in place after Event 2, the NRCA results tended to be more similar to the Berger and NWC results (Figure E-4) The Kolbusch laboratory cannot be properly evaluated with only 20 samples, but the seemingly higher values and specific laboratory procedures would need to be examined more closely to ensure comparability Different methodologies used in faecal coliform assays frequently yield differing results and may underlie the trends in the data from the present study Comparable results between laboratories is important not only for accuracy but for determining long-term trends in water quality which generally require participation of several laboratories

A more comprehensive intercalibration programme should be undertaken to determine the level of agreement or disagreement in results generated under present protocols It is possible, a detailed methodological assessment is required to determine the source of these difference, some of the potential areas for investigation are detailed below

In terms of evaluation of the four beaches being sampled, the high degree of precision and the accuracy of intercalibration of the Berger field laboratory, the NWC laboratory, and to some extent the NRCA laboratory, the QA data indicate a high degree of confidence in the quality of the field faecal coliform determinations being performed

3 Methodological Considerations

Overall the analytical results are showing good accuracy and precision However, the occasional positive growth on blind sterile samples and the tendency for counts to be higher in some laboratories compared to the Berger field laboratory should continue to be addressed Difficulties resulting in higher counts stem primarily from colonies being counted as faecal coliform which are actually other heterotrophic bacteria Higher counts are the typical result of identification issues This false positive counting can result from several methodological areas (1) not all colonies which appear blue on the plates are faecal coliforms, they must have a sheen and must be counted with fluorescent illumination on the microscope, (2) confirmations of both faecal coliform and non-coliform colonies using the gas production method must be performed, (3) temperature fluctuations or settings below the specified levels can result in higher growth of colonies, this can result from voltage problems, use of ovens versus water baths, or temperature calibration difficulties, and (4) periodic cross contamination from wastewater samples or from highly contaminated surface water samples, generally during filtration These methodological issues need to be evaluated for all of the laboratories However, given the small numbers of inter-laboratory comparison samples with two of the laboratories, additional comparisons will be needed before any supportable conclusions as to proficiency can be made This is an interim evaluation aimed only at guiding methodological examinations toward the goal of producing a uniformly accurate coliform testing approach for Jamaican waters

Table E-1

Laboratory Intercalibration

Turtle Beach and Sailor Hole Beach

SAMPLING EVENT 2 *28-September to 3-October, 1997*

Station No	Location		Water Depth (appr m)	Thursday 2-Oct 6 15h to 7 15h dry			
				Fecal Coliform (col/100 ml)			
				Louis Berger	NWC	NRCA	Kol-busch
OR- 1	Sailor Hole Beach	20 m from public beach	1 2	**35**	32	110	56
OR 2	Sailor Hole Beach	25 m from fishermen s beach	1 5	**30**	25	300	850
OR 4	Sailor Hole Beach	western cruise ship pier	>15	**19**	32		
OR- 5	Sailor Hole Beach	eastern cruise ship pier	>15	**35**	74	220	810
OR- 8	Turtle River	20 m upstream from its mouth	0 3	**1,500**	3 100	>1 600	5 700
OR 29	Turtle River	small tributary 100 m from mouth					
OR 31	Turtle River	at Da Costa Drive bridge	0 2				
OR 6	Sailor Hole River	30 m upstream from its mouth	0 3	**620**	2 676	1 600	>1 370
OR- 24	Sailor Hole River	spring bathing area for fishermen	0 2	**1**	9	300	270
OR 28	Sailor Hole River	confluence with spring water	0 2				
OR- 30	Sailor Hole River	laundry mat discharge basin	0 1				
OR- 9	Turtle Beach	west near Sand Castles	3 0	**10**	23		
OR- 11	Turtle Beach	east near Renaissance Hotel	2 1	**37**	125		
OR- 12	Turtle Beach	center beach	2 0	**720**	700	>1 600	>2 530
OR 13	Turtle Beach	central bay 100 m from shore	10 0	**5**	10	130	116
OR- 14	Turtle Beach	beach north of groin	3 0	**5**	7		
OR 20	Turtle Beach	10 m off groin	>15	**6**	12		
OR- 21	Turtle Beach	entrance to boat harbour		**43**	56		
OR- 22	Turtle Beach	end of boat pier		**110**	350	>1 600	>1 730
OR- 23	Turtle Beach	50m seaward from end of boat pier		**2**	10		
OR- 25	Turtle Beach	center of boat harbour					
OR 26	Turtle Beach	125m seaward from end of boat pier		**21**	7		
OR- 27	Turtle Beach	eastern end of cruise ship landing		**7**	3		
OR- 32	Fern Gully channel	downstream at Main Street bridge	0 05				
OR 33	Fern Gully channel	upstream at Shell gas station	0 05				
OR- 16	Turtle Beach	(Duplicate) *(3)*		50	108		
OR- 15	Blank (Clean Buffer Sample)			0	<1	<2	8

FC SEP97.XLS 1/7/98 10 36 PM

Table E-2

Laboratory Intercalibration

Turtle Beach and Sailor Hole Beach

SAMPLING EVENT 3 26-October to 2-November 1997

Station No	Location		Water Depth (appr m)	Wednesday 29 Oct 7 30 to 8 45h dry			
				Fecal Coliform (col/100 ml)			
				Louis Berger	NWC	NRCA	Kol busch
OR- 1	Sailor Hole Beach	20 m from public beach	1 2	**112**	250	80	>340
OR- 2	Sailor Hole Beach	25 m from fishermen's beach	1 5	**61**	138	80	>2 415
OR- 4	Sailor Hole Beach	western cruise ship pier	>15	**72**	60	110	>665
OR- 5	Sailor Hole Beach	eastern cruise ship pier	>15	**31**	30		
OR- 8	Turtle River	20 m upstream from its mouth	0 3	**15,000**	17 818	>1 600	>7 300
OR- 29	Turtle River	small tributary 100 m from mouth					
OR- 31	Turtle River	at Da Costa Drive bridge	0 2				
OR- 6	Sailor Hole River	30 m upstream from its mouth	0 3	**350**	730	280	>965
OR- 24	Sailor Hole River	spring bathing area for fishermen	0 2	**17**	27		
OR- 28	Sailor Hole River	confluence with spring water	0 2				
OR- 30	Sailor Hole River	laundry mat discharge basin	0 1				
OR- 9	Turtle Beach	west near Sand Castles	3 0	**0**	2	<2	>55
OR- 11	Turtle Beach	east near Renaissance Hotel	2 1	**0**	<1		
OR 12	Turtle Beach	center beach	2 0	**4**	5	15	253
OR 13	Turtle Beach	central bay 100 m from shore	10 0	**0**	<1		
OR- 14	Turtle Beach	beach north of groin	3 0	**1**	2		
OR- 20	Turtle Beach	10 m off groin	>15	**0**	3		
OR 21	Turtle Beach	entrance to boat harbour		**110**	125		
OR 22	Turtle Beach	end of boat pier		**200**	500		
OR- 23	Turtle Beach	50m seaward from end of boat pier		**0**	2		
OR- 25	Turtle Beach	center of boat harbour					
OR 26	Turtle Beach	125m seaward from end of boat pier		**0**	<1		
OR 27	Turtle Beach	eastern end of cruise ship landing		**11**	23		
OR- 32	Fern Gully channel	downstream at Main Street bridge	0 05				
OR- 33	Fern Gully channel	upstream at Shell gas station	0 05				
OR- 16	Ocho Rios	(Duplicate of OR 4)		56	27	130	>590
OR- 1	Sailor Hole Beach	(duplicate of OR 1)				130	>1 480
OR- 15	Blank (Boiled Seawater Sample)			0	<1	<2	0

Table E-3

Laboratory Intercalibration

Walter Fletcher Beach (Montego Bay) and Community Centre Beach (Negril)

SAMPLING EVENT 4 December 7 to 12 1997

Location		Station No	Water Depth *(appr m)*	Wednesday 10 Dec Louis Berger	NWC (MF)	NWC (MT)	NRCA
NEGRIL				8 45 to 9 45h dry			
North of Community Center Beach	1 500 m from mouth of S N River (to Negril Gardens Hotel) 5m from shore	NG 37	0 8				
	1 250 m from mouth of S Negril River (to Sandi San Hotel) 5m from shore	NG 36	0 8				
	1 000 m from mouth of S N River (at Bar B Barn Hotel) 5m from shore	NG 34	0 8				
	750 m from mouth of S N River (at Travellers Hotel) 30m from shore	NG 28		0			
	750 m from mouth of S N River (at Travellers Hotel) 5m from shore	NG 33	0 8				
	600 m from mouth of S N River (at Coral Seas Hotel) 30m from shore	NG 27					
	600 m from mouth of S N River (at Coral Seas Hotel) 5m from shore	NG 32	0 8				
	450 m from mouth of S Negril River 30m from shore	NG 1	1 6	2			
	450 m from mouth of S Negril River 5m from shore	NG 31	0 8				
Community Center Beach	340 m from mouth of S Negril River 30m from shore	NG 3	1 6	0			
	350m from mouth of S Negril River 5m from shore	NG 30	0 8				
	230 m from mouth of S Negril River 30m from shore	NG 5	1 7	0	*ed*		<2
	240 m from mouth of S Negril River 5m from shore	NG 25	0 8				
	130 m from mouth of S Negril River 30m from shore	NG 7	2 0	0			
	140 m from mouth of S Negril River 5m from shore	NG 29	0 8				
South Negril River plume	50 m northwest of northern jetty of river	NG 8	>6	0			
	50 m west of river mouth	NG 9	>6	1 100	*ed*	3 500	>1 600
	250 m west of river mouth	NG 26		280			
	450 m west of river mouth	NG 15		4			
	800 m west of river mouth	NG 23		0			
	1 300 m west of river mouth	NG 24		0			
South Negril River upstream	mouth of river	NG 10		760	*ed*	1 600	1 100
	250 m from mouth at N B Blvd bridge	NG 11		820	*ed*	1 700	340
	900 m upstream from mouth	NG 18		76			
	1 500 m upstream from mouth	NG 12		170			
	1 800 m upstream from mouth	NG 17		200	*ed*		300
	2 300 m upstream from mouth	NG 19		290			
	2 800 m upstream from mouth	NG 13		200			
	3 200 m upstream from mouth	NG 20		190			
	3 800 m from mouth at NWC ponds	NG 14		690			
	4 400 m upstream from mouth	NG 21		125			
	4 700 m upstream from mouth	NG 22					
Duplicates	Duplicate *(1)*	NG 16		0	*ed*		2
	Duplicate of NG 9	NG 9a			*ed*		>1 600
MONTEGO BAY				11 50 to 12 50h dry			
Walter Fletcher Beach	northern corner	MB 2	1 1	1			
	center north	MB 4	1 6	2			
	center south	MB 5	1 6	2	*ed*	2	220
	southern corner	MB 7	1 0	1			
	at southern groin entrance to beach	MB 8	0 3	0			
Dump up Beach	at southern groin entrance to beach	MB 13	0 3	0			
	center of beach	MB 14	1 2	1	*ed*		110
North Gully	between N Gully and Dump up Beach	MB 16	0 3	1	*ed*	940	>1 600
	10 m seaward from mouth	MB 15	0 3	>40 000	*ed*		>16 000
One man Beach	center of beach	MB 17	1 2				
Duplicates	(Duplicate) *(1)*	MB 9	1 0	0	*ed*		130
	Duplicate of MB 16	MB 16a	0 3	0			350
	Clean Buffer Solution	Buffer		0	*ed*		<2

NOTES *(1)* Duplicate stations Negril 12/10 NG 5 Montego Bay 12/10 MB 5
MT Multiple Tube Method
MF Membrane Filtration Method
ed Edited due to analytical quality control problems
Not available or not applicable

FC DEC97 XLS 1/7/98 10 37 PM

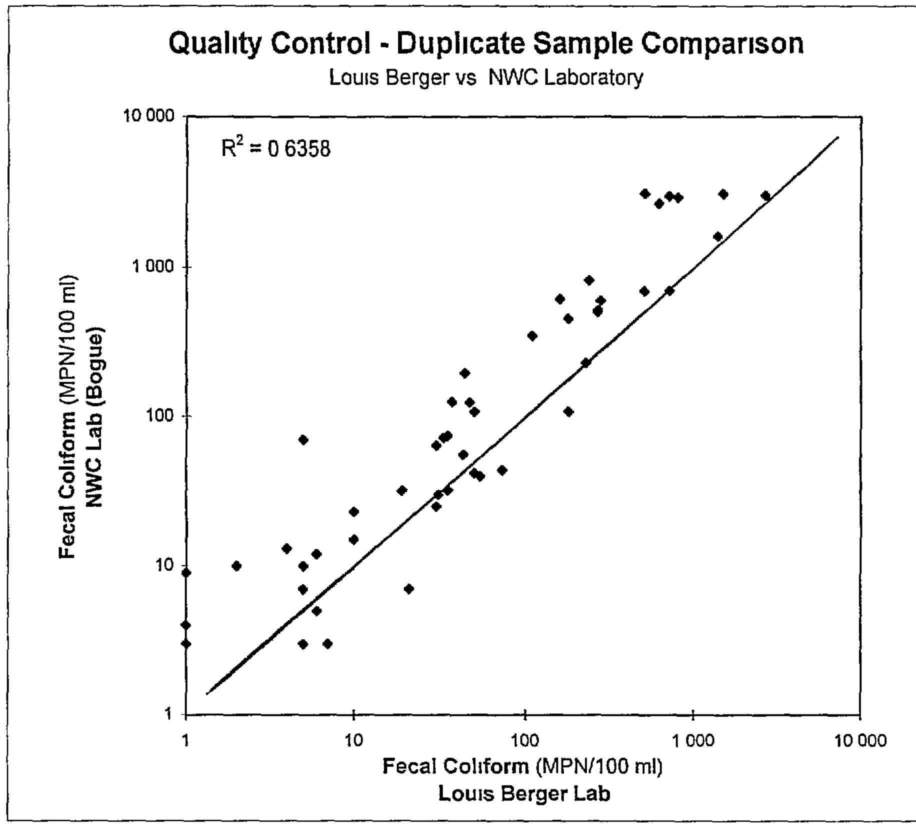
Figure E-1

Comparison of Duplicate Samples

Louis Berger vs NWC Laboratories

SAMPLING EVENT 2 28 September to 3 October 1997

	Louis Berger	NWC	
Ocho Rios	50	42	
29 Sep	180	108	
	73	44	
	54	40	
	1 400	1 617	
	230	230	
	5	70	
	44	196	
	180	456	
	160	616	
	31	30	
	47	124	
	30	64	
	270	520	
	1400		*ed*
	510	696	
	270	504	
Ocho Rios	2 700	3 050	
30 Sep	33	72	
Ocho Rios	35	32	
2 Oct	30	25	
	19	32	
	35	74	
	1 500	3 100	
	620	2 676	
	1	9	
	10	23	
	37	125	
	720	700	
	5	10	
	5	7	
	6	12	
	43	56	
	110	350	
	2	10	
	21	7	
	7	3	
	50	108	
	0	*1*	
Montego Bay	1	4	
29 Sep			
Montego Bay	5	3	
30 Sep	1	3	
	4	13	
	0	1	
	6	5	
	10	15	
	4	*0*	
	0	*0*	
Montego Bay	0	*0*	
2 Oct			
Negril	0	*0*	
30 Sep	0	*0*	
	0	*0*	
	0	*0*	
	0	1	
	240	823	
	280	600	
	710	3 000	
	510	3 100	
	800	2 927	
	0	*0*	
Total samples	60	59	



Notes

values reported as < were entered with 50% of their amount (marked in italics)

values reported with > were entered with 100% of their amount (marked in italics)

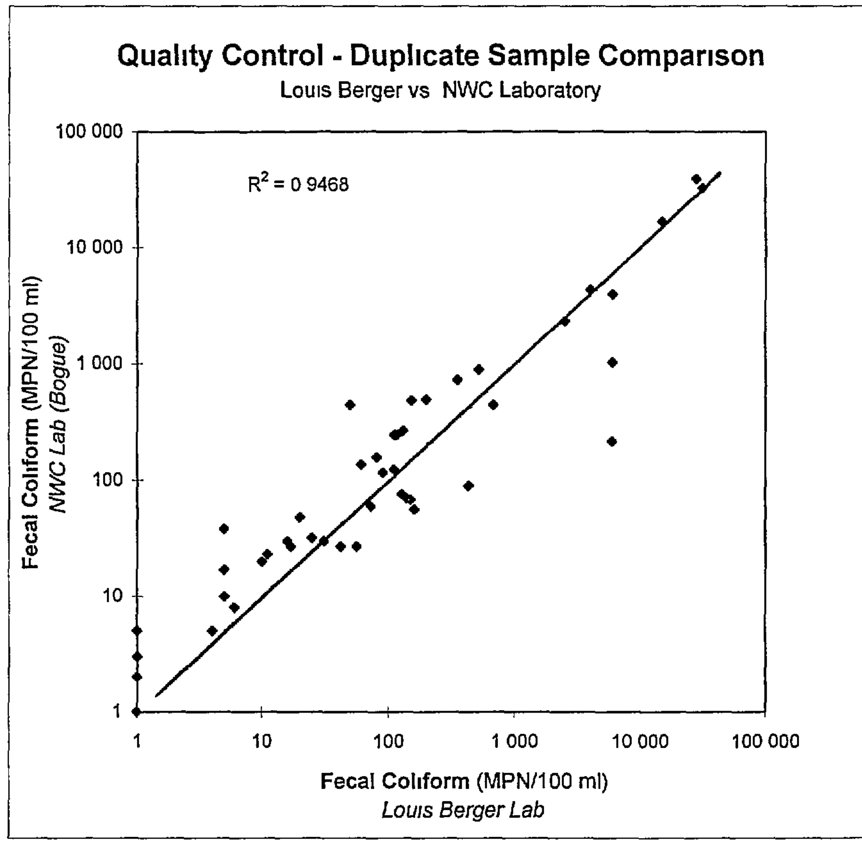
Figure E-2

Comparison of Duplicate Samples

Louis Berger vs NWC Laboratories

SAMPLING EVENT 3 26 October to 2 November 1997

	Louis Berger	NWC
Ocho Rios	140	70
27 Oct	42	27
	680	450
	31 400	33 636
	430	90
	10	20
Ocho Rios	150	68
28 Oct	160	56
	2 500	2 342
	5	10
	6	8
	5	38
Ocho Rios	112	250
29 Oct	61	138
	72	60
	31	30
	15 000	17 218
	350	730
	17	27
	1	2
	1	*1*
	4	5
	1	*1*
	1	2
	1	3
	110	125
	200	500
	1	2
	1	*1*
	11	23
	56	27
	1	*1*
Ocho Rios	128	76
30 Oct	90	118
	130	270
	28 000	40 000
	20	48
	117	250
Montego Bay	*6 000*	1 040
27 Oct	*6 000*	220
	50	450
	5	17
Montego Bay	520	900
28 Oct	153	490
	1	5
	4 000	4 360
Negril	25	32
30 Oct	*1*	*1*
	1	*1*
	6 000	4 000
	81	160
	16	30



Notes
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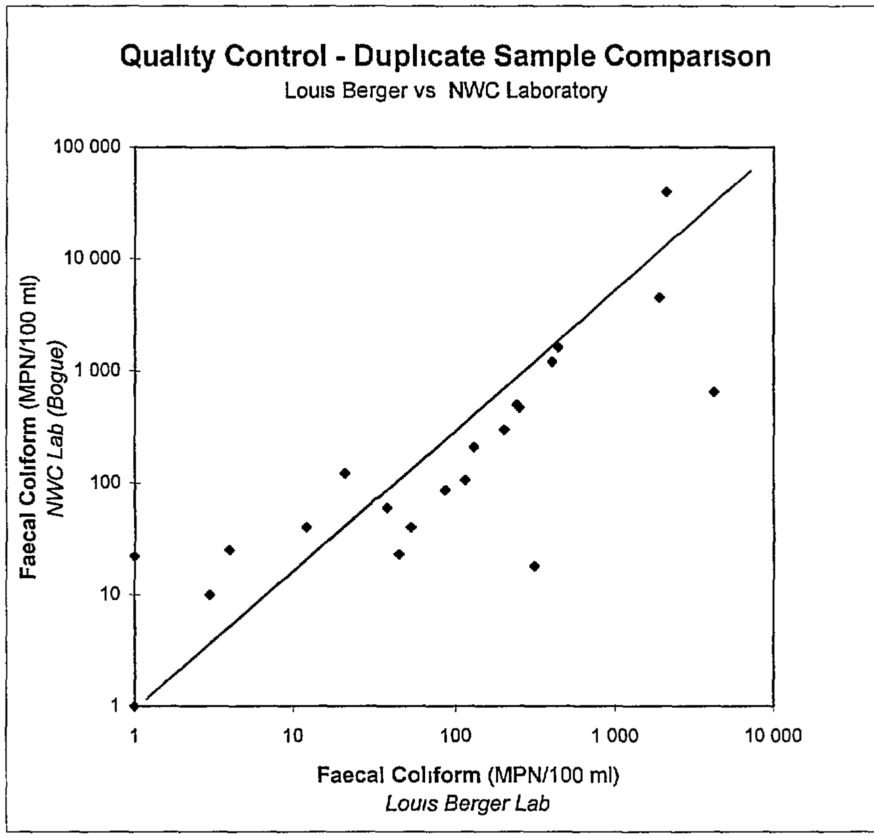
Figure E-3

Comparison of Duplicate Samples

Louis Berger vs NWC Laboratories

SAMPLING EVENT 4 December 7 to 12, 1997

		Louis Berger	NWC
Ocho Rios		38	60
	8 Dec	45	23
		86	86
		4 200	650
		4	25
		1	22
Ocho Rios	9 Dec		
Ocho Rios	10 Dec		
Ocho Rios		21	122
	11 Dec	310	18
		53	40
		2 100	40 000
		250	470
Negril		200	298
	8 Dec	12	40
		3	10
		1 900	4 500
		240	500
Negril		*1*	*1*
	11 Dec	400	1 200
		114	106
		440	1 613
		130	207



Notes
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Figure E-4

Laboratory Intercalibration

(Sampling Event 3 October 28, 1997)